THE
ENGINEERING REVIEW.

Edited by
C. EDGAR ALLEN.

Vol. XVI. JUNE, 1907. No. 6.

Engineering Works in the Crown Colonies.

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It is hardly a paradox to say that the Colonial engineering works which possess human interest of the most intimate kind are those which have been undertaken in the infant Colonies. The reason is not far to seek. In the embryo colony, the administration, starting with no experience of such matters, encounters in the construction of public works a running stream of difficulties of the most strange and unexpected nature. Such enterprises are afflicted in their early days with such incidents as attacks by wild beasts, fevers, tribal wars and tribal feasts, the most ridiculous sorts of native pilfering, floods, washouts and accidents of all kinds. In the contest with such difficulties the whole ingenuity of man is brought into play, ample incident is found, and the interest is well sustained. An atmosphere of the most refreshing and entertaining, not to say ingenuous and diverting, nature is introduced through negotiations conducted in a delightful childlike kind of language with the native potentates. In these negotiations and in all else that relates to the construction of engineering works the final authority rests with the Secretary of State, and when he has decided to enquire into the merits of any proposed work, instructions are given to the Crown Agents for the Colonies, who obtain an engineer's report on the project, discuss it in its general bearings on the welfare of the Colony, and then, if the Secretary of State approves, arrange for the necessary staff and materials to be sent out forthwith. In the case of great works the obtaining and testing of the necessary materials is no small matter, but the department is well accustomed to deal with such enterprises.

When it occurs to a young colony that it would like to grow, its first cry is usually for a harbour, and its next for a railway. Sometimes a happy fate has already provided a natural harbour to which relatively little needs to be done, but, in most cases, costly works would be required. So costly, that it often happens that the cry for a harbour is little more effective than a cry for the moon, and a railway scheme has to come first.

A description of all such works in the

Crown Colonies would certainly be interesting, but the space it would take up prevents its being attempted here. A few representative cases will, therefore, be taken of each of the more important and more novel types of public works, such as the railways in Ceylon, Federated Malay States, and the Straits Settlements; the Colombo Harbour Works, the Electric Power Station at Kaula Lumpor in Selangor, the railways in West Africa and Jamaica, the Trinidad-Tobago Wireless Telegraphy Installation, the Ceylon Pearl Separating Plant, and the Ceylon and Federated Malay States Petrol Motor Transport schemes.

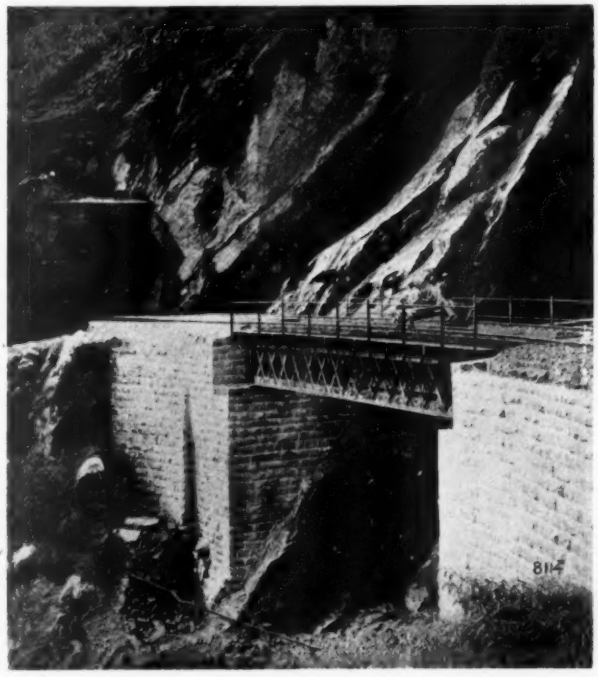
THE CEYLON GOVERNMENT RAILWAYS.

No Crown Colony has more important engineering works than has Ceylon. A wise administration presiding over a thrifty populace has enabled the Government to undertake enterprises of great importance and cost. The island is far from being completely served in respect of railway systems, but a good start has been made, and there are 560 miles of line now open, all but 68 miles of which are of the broad 5 ft. 6 in. gauge and the rest of a narrow gauge of 2 ft. 6 ins.

Railway construction started in Ceylon in the year 1857 and after ten years of difficulty and labour a line 74 miles long was opened to Kandy, the old capital of the island. This work necessitated rock cutting and blasting on a huge scale, and, the various difficulties met with causing the collapse of the Ceylon Railway Company, to which the concession for the railway had been entrusted, the Government had to call in a contractor to finish the line, of which the final cost proved to be more than twice the amount originally estimated. This was not altogether a happy experience for the Government, and it is not surprising that railway construction ceased for some years. In 1871, however, it was resumed, and a contract was made for a branch line to Nawalipitiya, which was carried out successfully. Further lines, from Colombo to Kalutara, and Kandy to Matale, were then built in the same manner, and the colony had every reason to be satisfied with its further experience of construction by contractors. The departmental system by which the colony is its own constructor, has its own construction staff, and takes upon itself all risks, had not yet been tried. The death blow to the contractor system of construction was soon to come. In 1880 a contract was let for the construction of a railway from Nawalipitiya to Nanu Oya, in the hill country, and from that date to 1885 there were perpetual disputes with the contractor. Large claims were rendered against the Government upon various counts, and these had to be arbitrated upon. The Government had to incur an immense expense in watching the execution of the works, and, when the last mile of that railway was completed, construction by contract ceased in the island, and has never been resumed. By that time 176 miles had been built, all upon the 5 ft. 6 in. gauge, and no extensions were taken in hand for a number of years. When work was resumed it was by the departmental system above referred to, and in six years the lines to Alutgama, Haputale, Galle, Bandarawela, Kurunegala, and Matara were built, a total mileage of 117 miles, again all on the 5 ft. 6 in. gauge. For the construction of these lines the Government were fortunate in having the services of a very skilled resident engineer, Mr. F. J. Waring, C.M.G., M.Inst.C.E., and it was greatly owing to his ability that the Departmental system of construction became so successful. On the completion of these lines railway construction ceased for some years. In 1899 it was resumed on the departmental system, Mr. Waring supervising the work from home as a partner in the firm of consulting engineers to the Government, and these lines were taken in hand, and are now completed. One of them was a line very greatly exceeding in length any section which had previously been undertaken, being the 200 miles between Kurunegala in the centre of the island

and Kankesanturai at the northernmost point. This section was of the 5 ft. 6 in. gauge. The other two lines, the Uda Pussellawa and the Kelani Valley lines, were only of a joint length of 68 miles, and the experiment was made of building them on a gauge of 2 ft. 6 in., thus introducing the first break of gauge in the island.

The capital cost of the Ceylon railway system to December 31st, 1904, was Rs. 70,900,000, but since the initiation of the railway system there has been paid as sinking fund no less than Rs. 12,200,000, and as a contribution to the finances of the colony, after paying interest and sinking fund, the still larger sum of Rs. 36,900,000. The result is that the capital outstanding on loans on January 1st, 1904, was only Rs. 40,400,000. The history of railway construction in Ceylon is a very interesting one, as bearing upon the relative merits of the two methods of railway construction, and it has been officially recorded (Cd. 2325/1904) that "in Ceylon the question of labour supply is fairly settled, the climate is known, and there have been no wars or other serious disturbing influences. Everything therefore would appear to be favourable to the contract system. The experience gained does not, however, point to any superiority on the part of that system."



CEYLON RAILWAYS. HAPUTALE LINE BRIDGE AND TUNNEL.

TRINIDAD-TOBAGO WIRELESS TELEGRAPHY.

Great enterprise has been shown by the Government of Trinidad in installing a system of wireless telegraphy between the islands of Trinidad and Tobago. The system used is the Lodge-Muirhead, and its erection and general supervison were entrusted by the Public Works Department to the care of Mr. C. C. F. Monckton, electrical engineer to the Government of Trinidad, and a former student of Professor Ayrton's. The particular points which it was desired to connect were Port-of-Spain in Trinidad and Scarborough in Tobago, a distance of fifty-seven miles in a direct line. The route by which the messages pass is partly telephonic and partly telegraphic. Along the first twelve miles or so of the route a telephone line has been erected, by which the messages are transmitted to North Post, on the north coast of the island, there to be sent off by means of wireless telegraphy to Tobago, distant about fifty-six miles. The

scheme, as outlined above, has been quite successful, and it is now open for the use of the general public.

At first it had been desired to communicate direct between the two capitals by means of wireless telegraphy, but it was found that the station of Port-of-Spain was screened by the intervening hills of about 3,000 ft. altitude, and the signals could not get through; although they were picked up by a steamer lying a few miles out in Port-of-Spain Harbour.

The aërial used is a carpet of 5,000 sq. ft. at a mean height of 60 ft., and the wave length generally used is about 500 metres. The transmitting apparatus was originally worked by a 3 h.-p. "Petter" oil engine, driving a 1½ k.w. alternator generating current at a frequency of 200.

The system was opened for public use on January 2, 1906, since which date it has been working successfully, being mainly occupied with the transmission of the daily bulletin of news to Tobago. On account of the relatively small number of messages requiring to go through it was not considered economical to keep the original plant always running, and it was, of course, inconvenient to have to start up the engine for each message; so it was decided to work from storage cells, and a duplicate plant has consequently been fixed at each station, consisting of a 1½ h.-p. "Petter" oil engine, driving a dynamo for charging a small battery of chloride cells for working a 12-in. "Sullivan" induction coil. This extra plant is now in use, and readable signals have been received on the "Lodge-Muirhead" coherer at midday in August, with six cells discharging at 5 amperes through the induction coil. The difficulties due to tropical conditions were of no mean order, and great credit to the energy and skill of the officer responsible, viz., Mr. C. C. F. Monckton, and the staff of local operators which he has trained, and who are responsible for the continuous working of the system.

THE COLOMBO HARBOUR WORKS.

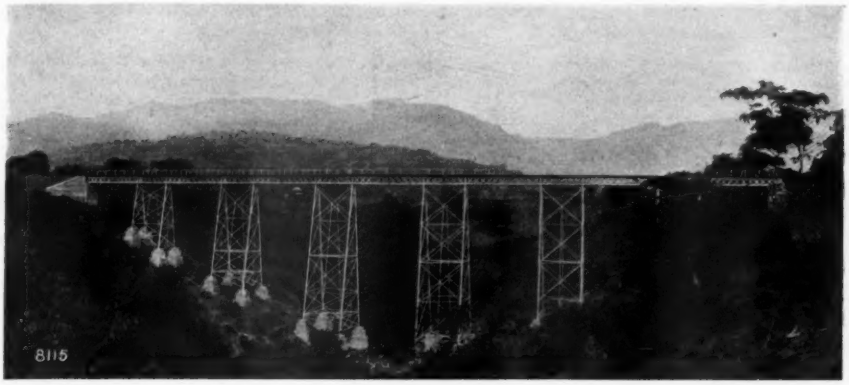
The Colombo Harbour Works form one of the most considerable undertakings of the kind that there are in the world. The area of the harbour is as much as 660 acres, or over one square mile, with a depth ranging up to 39 ft. at low water. Protection is afforded by three arms, of which the central (or north-west) one is an island work 2,656 ft. in length, whilst the two side arms are respectively 4,210 ft. (the south-west arm) and 1,100 ft. (the north-east arm) in length.

The south-west arm was started in 1873, the foundation stone having been laid by the present King, and completed twelve years later. Both the other arms were started in 1894, and both are now finished. The north-east arm is a rubble embankment tipped from a staging, but the other two are of a more ambitious construction, being built of concrete blocks weighing from 18 to 30 tons, set on a sloping bond system. Two entrances are available, one of 700 ft., and the other of 800 ft. This provides amply for all nautical purposes, and affords facilities for the motion of the tides to change the water in the harbour and so keep it sanitary.

There is also a graving dock, 700 ft. in length, but this is not wholly a colonial work, as the Imperial Government paid a large portion of its cost. It was begun in 1899, and is now just completed. In the same year work was started on a patent slip, and four years later it was completed, to the contemplated length of 800 ft. The total capital cost of the whole of the harbour works to June 30, 1905, is given as £2,300,000, and that this expenditure was wisely undertaken, is shown by the immense trade which now comes to Colombo. Whether this prosperity will in any way be affected by the construction of the Panama Canal remains to be seen.

It may be mentioned that the Colonial Government have provided for the wants of the fishermen displaced by the construction works and by the building of the coaling jetties, by making a separate fishery harbour for them on the other side of Mutwal Point.

The whole of the works, including the contemplated lengthening of the

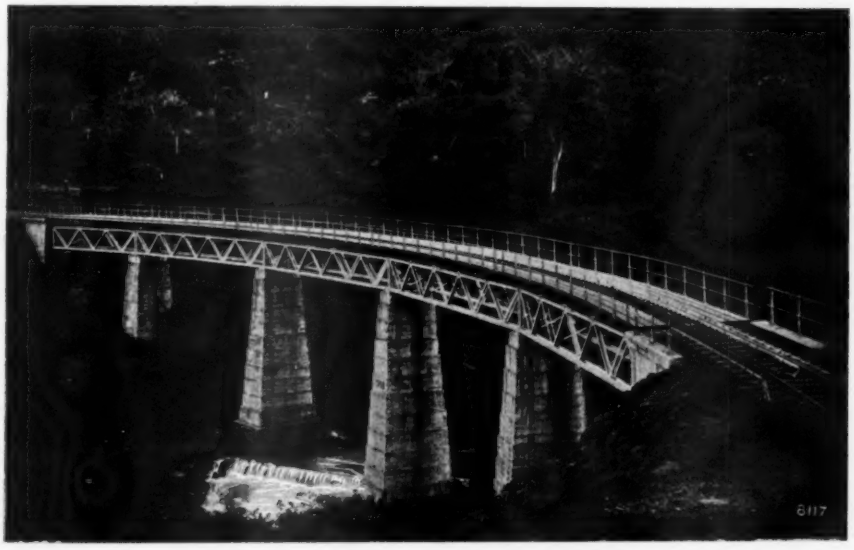


SIERRA LEONE RAILWAY. MAROON VIADUCT.

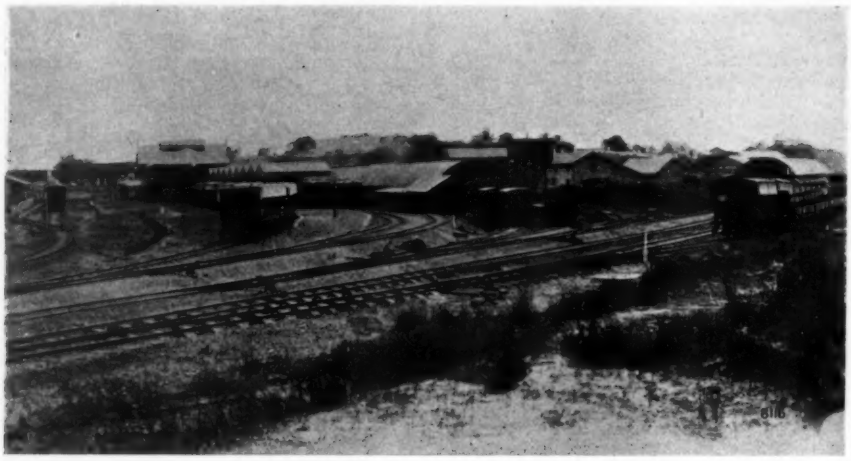
south-west arm, have been to the designs of the eminent firm of Messrs. Coode, Son and Matthews, Consulting Engineers to the Crown Agents, and the work of construction has been carried out by the Government without the aid of a contractor.

THE WEST AFRICAN GOVERNMENT RAILWAYS.

The railway lines in West Africa have all been built in the last ten or eleven years, and although known under the general title of West African Government Railways, they are really three



SIERRA LEONE MOUNTAIN RAILWAY. CONGO VIADUCT.



GOLD COAST RAILWAY. SEKONDI STATION AND YARD.

entirely different systems of lines in three Colonies which are not even adjacent to one another, although all on the same west coast. This means that anything of the nature of intercommunication is impossible except through the territories of other European or African Powers, and up to the present no lines have been constructed in the non-British Colonies which could be so connected up. It is not that there are no railway works in those territories, but merely that their direction and extent are not such as to make connection at the present time a feasible project. The railway systems in the three British Colonies are of two gauges, 3 ft. 6 ins. and 2 ft. 6 ins., so that there is no strict uniformity here, and, indeed, the only common interests which they have, are the general similarity of climate, the fact that they are under the same type of administration from the Colonial Office, that the same Consulting Engineers advise on them, and that interchanges of railway construction staff have occurred between Colony and Colony. The Consulting Engineers in question are the firm of Shelford, first under the title of W. Shelford, then as Shelford & Son, and finally, on the regretted death of Sir W. Shelford, when his son joined Sir B. Baker, the title of the firm became Baker & Shelford.

The three Colonies in question are: Sierra Leone, Gold Coast, and Lagos (or as it is now termed, S. Nigeria).

Sierra Leone Government Railway.—The longest of these three Colonial railway systems is the Sierra Leone railway. It runs nearly eastward from the capital, Freetown, to Baiima, a town within a few miles of the Liberian frontier. Further railway construction in the colony in this direction is confined by geographical limitations, and any further construction will probably be in another direction from Freetown, although it has to be borne in mind that the tendency in the future may be to construct roads for motor traffic, rather than railways of the existing type. The early surveys for the Sierra Leone Railway were carried out under great difficulties, and the pioneer work of Major Festing, in the Eighties, was so arduous as to lead to the death of that able and versatile officer. The gauge of the line is 2 ft. 6 in., and the total length to Baiima is 222 miles. The bridge work has in many places been extremely heavy, as the views illustrate, but in spite of this the

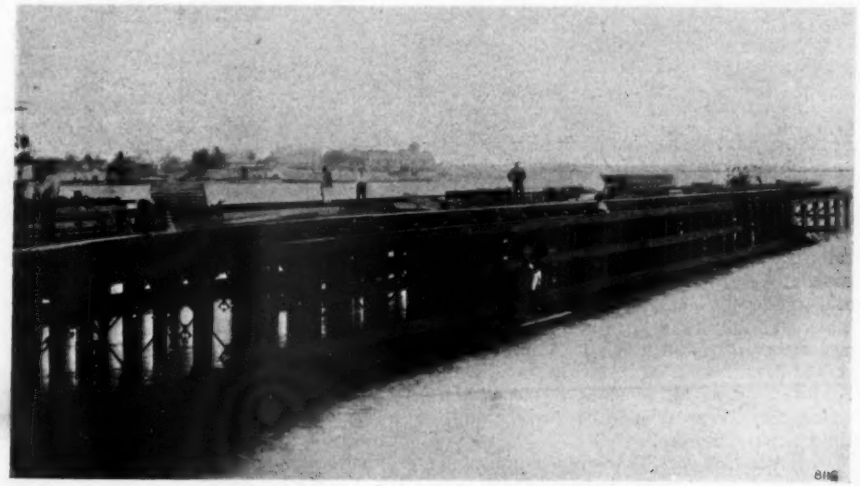
cost per mile has only been about £4,000.

In Freetown itself, a short mountain railway, about 6 miles in length, has also been constructed as part of the same system and on the same gauge. The slope is 1 in 23 for a large portion of the route, and the working is by means of steam locomotives. The idea of halving the distance by taking a steeper slope and using electric power from an existing power station was attractive, but was eventually set aside, although, if the problem had come up for solution some years later, it is possible that something more like an electric tramway would have been built. The photograph of the Congo viaduct shows the heaviest work on this section.

Gold Coast Government Railway.—This railway is the outcome of a keen agitation on the part of various mining companies who were very actively at work during the great mining boom about 1899 and 1900. Mining activity on the Coast has shown some fluctuation since then, but the railway has now been completed, thus giving a better chance for the development of sound business, albeit leading to the curtailment of speculative ventures owing to the impossibility of now covering over any failures in operation by allusions to the lack of all communication proving fatal to successful endeavour.

The line runs from Sekondi on the coast to Kumasi, the old capital, and is 168 miles long. Railway construction was started on the 3 ft. 6 in. gauge in 1898, and was much interfered with by war and by the unhealthiness of the climate. That the cost per mile was as high as £10,000 was due to the causes above stated and to the high cost of labour owing to the competition from the mines and to the immense cost of creating, virtually out of nothing, a large base, such as Sekondi. A view of Sekondi is shown.

Lagos Government Railway.—This line, like the Sierra Leone Railway, has the advantage of starting from a considerable city, and it will shortly assume the position of being the most important of all the West African railways, as it will tap the vast and wealthy provinces of Northern Nigeria, at present only accessible to trade by the uncertain facilities which the river Niger affords or by the caravan routes of the Sahara



LAGOS RAILWAY. IDDO WHARF EXTENSION WORKS.

to the Mediterranean seaports. It is hoped to open the line to Oshogbo by the middle of 1907, a distance of about 200 miles, all on the 3 ft. 6 ins. gauge. Construction work beyond Ibadan is now rapidly proceeding, and it is contemplated to reach the Niger *via* Oshogbo, Illorin and Jebba. As part of this work has been carried out subsequent to the findings of the Engineering Standards Committee on flat bottomed rails, the Government decided to increase the rail weight from 50 lbs. to 55 lbs., and to adopt a British Standard Section. This action is in fulfilment of the Secretary of State's desire that the recommendations of the Engineering Standards Committee shall be adhered to as strictly as possible for work for the Crown Colonies.

Nigerian Railway Schemes.—At present the only railway in Northern Nigeria is a short length of very light line between the river Kaduna, a tributary of the Niger, and Zungeru, the capital. Larger schemes are, however, in contemplation, and as has already been mentioned, it is planned to carry the Lagos line to the Niger. On reaching the river either a bridge or a ferry will be needed; once across, there is nothing to prevent the railway being carried on to Zungeru, Zaria, and even Kano, the great objective of the caravan routes. Two points must, however, not be lost sight of. One is that once goods have been got down from the North to the Niger, the railway will have to face the competition of rates, *via* the Niger, to the sea, instead of going on by the railway over land to Lagos; and the other consideration, of a very different nature, is that by the time railway facilities are available, the Northern Nigeria Administration may have found a solution to its transport problem in some sort of motor transport

JAMAICA RAILWAY. BROCADOO CUTTING.

on ordinary roads. The construction of roads suitable for motor transport would mean that in providing the roads for the opening up of the country, the permanent way for petrol cars would also be provided. A problem of this kind can only be settled by the experience of those who are familiar with the country. The possibility of killing two birds with one stone is always attractive.

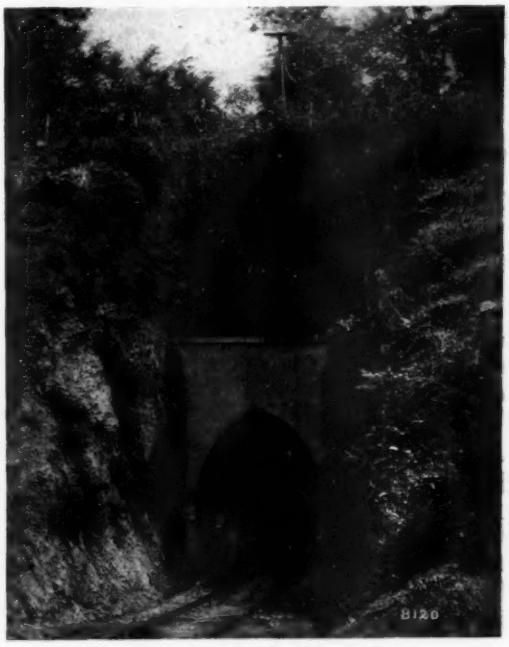
JAMAICA RAILWAY.

The first section of railway in the island was started as long ago as 1844 and its history since then has been checkered indeed. The railway works were first in the hands of a private company. Then the Government had to intervene and, after purchasing the line, reconstruct it. Extensions to Porus and Ewarton were then undertaken on the contract system, Messrs. Hawkshaw and Hayter acting as consulting engineers. The consulting engineers' plans were, however, not carried out as strictly as they should have been, with the result that the contractors were able to demand large sums as extras to their contract. In the end it was found that up to 1885 the railway had cost £833,000 for its 65 miles. The financial prospects of the undertaking now began to improve, but in 1889 a private company was again allowed to take possession of the line, and when, ten years later, the company was wound up, the Government had once more to intervene and practically buy the line back again. This repurchase cost £2,481,862, as the length of line was then 185 miles, all on the 4 ft. 8½ in. gauge. The very heavy price which the Government have had to pay for the railway will of course always render the capital charges much more heavy than those which most other Colonial Governments have to bear for undertakings of equal dimensions.

The illustrations show views of the Brocadoo Cutting and Long Hill Tunnel.

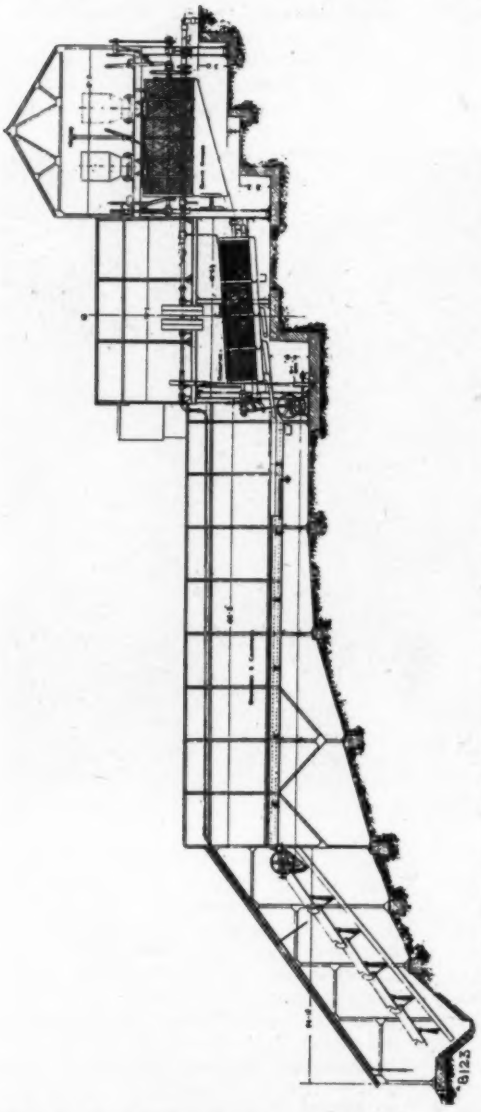
THE CEYLON PEARL SEPARATING PLANT.

This plant was invented by Mr. G. G. Dixon when in Ceylon on Government service, and it is certainly of the greatest interest and ingenuity. For over a century (*i.e.* ever since the English have held the island) the method of obtaining pearls from oysters had been by the labour of natives collected from India and all parts, who were formed into a huge and very unsanitary camp in the northern part of the island. In addition to the obvious disadvantages of this method, there was the one that the Government never got its agreed share of the proceeds owing to the dishonesty of some of the natives. Mr. Dixon's machine, as perfected by



JAMAICA RAILWAY. LONG HILL TUNNEL.

him in collaboration with Messrs. Kirkland and Capper, consulting engineers to the Government, was able to receive the oysters by the hundred thousand and using a continuous process to extract the pearls and then deliver the proceeds into three separate compartments, into which fell the shells, the non-valuable part of the "saraku," and lastly the pearls themselves. This was effected by allowing the oysters to rot and then feeding them into the washing screens, where the shells were separated from the "saraku" (the local name for the chipped shell, bissus, sand, pearls, &c.). The shells were then collected together and were ready for sale as a by-product. The "saraku" itself passed through the meshes of the washing screens and was then carried by running water into a revolving screen called the classifier, which was sprayed with jets of water. In this screen the pearls, together with small pieces of chipped shell, &c., were separated from the rest of the "saraku," and taken on to a drying belt conveyor to the separators, which were inclined metal plates down which the mixture rolled, so separating the smooth round pearls from the rest of the "saraku." The "saraku" thus separated in the classifier contained only very fine seed pearls, and even these were not lost, as the "saraku" was sold as a further by-product. The pearls were then collected in buckets.



PEARL SEPARATING PLANT BUILT FOR THE CEYLON GOVERNMENT PEARL FISHERIES BY MESSRS. FRASER AND CHALMERS, LTD.

In order to see whether the machinery succeeded in catching all the pearls, a quantity of seeds and beads, to represent pearls, were mixed with a number of oysters and the whole put through the machine. For several reasons these imitation pearls were more difficult to catch than the true pearls, but even so it was found that, in three trials, out of a total of 160 beads and 20 seeds which had been mixed with a total of no less than

775,000 oysters, the machine caught and separated as large a proportion as 147 beads and 19 seeds, showing an efficiency of 92 per cent., a very satisfactory figure.

It will be admitted that great praise is due to those who were responsible for this ingenious invention, and most of all to Mr. Dixon (whom the writer has to thank for supplying the above figures), who was not only the originator of the scheme, but who actually erected the plant in an almost inaccessible spot, amid the greatest difficulties on account of labour, fever, climate, &c.

FEDERATED MALAY STATES RAILWAYS. VICTORIA BRIDGE, PERAK RAILWAY.

FEDERATED MALAY STATES AND STRAITS SETTLEMENTS RAILWAYS.

There are now open about 410 miles of line in the Federated Malay States and some 40 miles in the Straits Settlements, all on the metre guage. The whole of this great work, with one exception, has been carried out in a highly satisfactory manner by the Departmental system under the advice of Messrs. Gregory, Eyles and Waring, as Consulting Engineers. The one exception is the 25 miles of line between Seremban and Port Dickson in the State of Negri Sembilan, and in relation to this short section the experience of the Government was unfortunate, as the terms of the concession were so worded as to give the company a great advantage, and when certain difficult points had to be submitted to arbitration, the decision went against the Government. This line was completed 15 years ago and it is not surprising that no further concessions for railway construction have been let to anyone and all subsequent lines have been built by the Government themselves with their own staff of constructors.

These railway systems have been built almost entirely out of surplus revenue and not out of loan funds. This procedure is not always economical as it may lead to undue protraction of the construction work; in these States, however, revenue was so flourishing that funds were continuously available and no such difficulties occurred. Having regard to the fact that the total cost of these lines is well over £3,000,000, it

will be admitted that this is a highly satisfactory result and that great credit is due to those who administered the Government.

The F.M.S. Railway Department is now constructing a further line of 120 miles in length through the State of Johore, and when this is completed there will be a continuous line from the city of Johore (opposite the island of Singapore) to Penang in the extreme north of the States. The Johore extension, like that in the Colony of Southern Nigeria, is being built with rails of a British Standard Section, in this case 80 lb. per yard.

SINGAPORE DOCK EXTENSION RAILWAY.

THE KUALA LUMPOR ELECTRIC POWER SCHEME.

This scheme is a very good example of how advantage may be taken of the presence of water power to generate electricity for lighting and power. Water is taken from the Gombak River in the State of Selangor in the Federated Malay States and utilized in turbines which drive three-phase alternators generating at 6,600 volts. Electric energy is then transmitted over a distance of about ten miles to the State Capital, Kuala Lumpor, where it is transformed down at a sub-station by means of motor generators to a continuous current three-wire distribution with 440 volts across the outer wires. In addition to this distribution three-phase current at 400 volts and 40 periodicity is used in the Government Railway Workshops in the city. The estimated minimum flow of water when the scheme was put in hand was 1,400 cubic ft. per minute with a head of 310 ft. The capacity of the plant, which was supplied and erected by the Oerlikon Company, is 1200 h.p., but half of this is intended as a standby, and additional steam power is available in case of need. The plant has now been got under weigh and current is being taken by the Government for general street and office lighting and for the railway shops, besides which the surplus is being sold to outside consumers. Messrs. Preece and Cardew, the Consulting Engineers for the scheme, are to be congratulated upon its successful realisation in spite of many difficulties. There would appear to be no reason why the undertaking should not be financially as well as mechanically successful now that the Government have taken the plant over and shown themselves determined to work it to the best advantage.

MOTOR TRANSPORT.

Motor transport is in its infancy so far as the Crown Colonies are concerned, but it appears to be a sturdy infant and gives every prospect of rapid and healthy growth. A Thornycroft 24 h.-p. petrol chassis has lately been sent out to Ceylon to be used for mail and passenger transport in the interior of the Island. If it is successful it is contemplated to run a fleet of similar

vehicles on an extended service: the use which such a service would have as feeder of the railway system would be very great indeed. For a similar service in the Federated Malay States a number of chassis have recently been built by Messrs. Thornycrofts, The Albion Co., and Messrs. Milnes-Daimler, and will be put into service immediately on arrival. This enterprise on the part of the Government means sinking a good deal of money, but there is no doubt but that such a scheme, if ably carried out, should show a satisfactory return to the Government either directly or through increased business on the Railway system. In Southern Nigeria a number of Albion motor vans are being put into use for the carriage of cotton down to the railway and for other purposes.

Besides these heavy vehicles a number of light cars have been sent out recently to several Colonies for the use of Colonial Governors, State Engineers, and the like. Indeed, in view of the facilities such cars afford in carrying out official duties, it is surprising that more Colonies have not already decided to adopt them. At first there was the risk of getting a car which would require continual supervision and repair, besides being unreliable in running; cars are, however, so much improved now in design that little more than intelligent handling is required, and that the Colony will at least get a car *capable* of travelling satisfactorily is safeguarded, so far as safeguarding is possible, by the tests on the road carried out by the Crown Agents Engineering Inspection Department before the car is actually paid for.

In conclusion the writer desires to express his indebtedness to the Crown Agents for the Colonies for allowing him facilities for the compilation of this article. He also has to express his thanks to Sir William Matthews, K.C.M.G., Mr. F. Shelford, M.Inst.C.E., Mr. F. J. Waring, C.M.G., M.Inst.C.E., Mr. A. Preece, M.Inst.E.E., Mr. G. G. Dixon, Mr. C. C. F. Monckton, and Miss Dorothy Capper, daughter of the Jamaican Director of Education, either for illustrations or information about the works described. It must of course be understood that whenever the writer has expressed particular opinions they are so expressed as his and his alone.

Present-Day Engineering in the Transvaal.

MINING AND METALLURGICAL MACHINERY.

By A. McA. JOHNSTON, M.A.

THE foundation of all engineering practice generally resolves itself into the question of the quality and price of coal available for motive power. It has been said, and with a great deal of truth, that the mines of the Witwatersrand are practically dependent on the close proximity of the coal beds for their dividend paying capacities. Without cheap fuel it had not been possible to mine the low grade ore on which the industry almost in its entirety depends.

The sources of coal supply are three in number, all of the districts contributing a long flaming or bituminous coal; the essential difference in the qualities lies in the amount of ash found in each. The Brakpan-Springs area supplies coal inferior to any found in the Middleburg district and even of less evaporative power than several of the Heidelberg properties, but its coal finds a ready market and commands a better price at the pit mouth than either of the other districts on account of its proximity to the gold mines.

Representative analyses of each of the districts may be given as follows:—

	I.	II.	III.
Specific gravity (15° C.)	1·62	1·50	1·54
	Per cent.	Per cent.	Per cent.
Fixed carbon	55·58	64·18	48·84
Volatile matter	17·80	17·26	24·64
Sulphur	0·92	1·50	1·53
Ash	22·56	16·05	20·80
Moisture (at 110° C.)	3·14	1·01	4·19
Evaporative factor	9·96	12·09	9·50
	Non-caking.	Caking.	Non-caking.

The evaporative factor expresses the pounds of water evaporated by one pound of dry coal and is reckoned on the results obtained by the Mahler's Bomb Calorimeter. No. I. is an average coal from the Springs-Brakpan area, and this can be bunkered on the mines to the east of Johannesburg at a cost of about 10*s.* 6*d.* per ton. No. II. is mined in the Middleburg district and the approximate cost delivered to the same area would be 14*s.*, whilst No. III. is the analysis of Vereeniging nut coal, which shows a large amount of volatile matter and which would cost, delivered, just over 12*s.* The cost of all coals to the gold mines varies of course directly as their distance from the source of supply; as for example, mines at the far east end, Van Ryn, New Kleinfontein, &c., pay but 8*s.* per ton for Brakpan coal, whilst the Krugersdorp mines have to debit themselves with nearly double this amount. It is difficult to classify the various coals when speaking of their clinkering properties, as every coal mine has to be more or less judged on its own merits, but roughly speaking it may be said that No. I. coals form a hard coherent clinker, No. II. a slightly compact clinker, and No. III. a fairly friable clinker in the furnace.

Sources of Power.—These analyses show that all the coals are quite suitable for gas-producers, and no trouble need be experienced in building producer plants capable of burning these to the best advantage. How far such plants will come into favour in the near future it is difficult to forecast, but it is interesting to note the several suggestions that have recently been forthcoming to supply the gold mining industry with power.

Firstly, there is a scheme on foot to utilize the Victoria Falls for producing an electric supply to be conveyed some 1,200 miles to the Witwatersrand.* The

* Cf. THE ENGINEERING REVIEW, Vol. XVI., pp. 1 and 51.

African Concessions, Limited, has already given notice that they intend applying for a private ordinance during the present term of the Legislative Assembly that they may obtain power to attach land on which to construct dams, reservoirs, track lines and generating stations. It is reported that £3,000,000 has already been privately subscribed with this object and the fact that the British South African Company has asked the Rand Water Board for their lowest price for water delivered to a site near Rosherville Dam lends colour to the further carrying on of the scheme.

A little consideration shows many difficulties to be overcome ere the concern becomes a payable one, but sufficient notice may be taken of three things only, viz., that Rand companies at present at work are very little likely to dismantle the existing generating plants for the sake of obtaining this electric supply; that the mining of the deeper deep mines is not now so eagerly looked forward to as was the case some years ago; and again, the installation of an auxiliary plant to take up the work at a moment's notice should the supply from the Falls fail, condemns the scheme. Another suggestion that generator gas be produced at the coal mines and led by pipes along the Reef for consumers, though practical enough, has met with little enthusiasm.

Central Power Stations.—Rand engineers are exceedingly conservative, and innovations of a drastic character are invariably looked at askance—"*festina lente*" may well be their motto, a considerable experience having taught them the wisdom contained in these words. The scheme at present most in favour is the central electric power station for a group of mines. This system was inaugurated some eleven years ago at the Rand Central Electric Works situated close to the coal fields and adjacent to a "pan" of water near Brakpan. Designed to supply power to the whole reef and to provide Johannesburg itself with light, this plant has lately given good encouragement to the promoters, and the Board has decided to increase the present plant by additional units of about 2,500 kw. each. At present there is in use one steam turbine, and for the proposed enlargement it is intended to erect others to act as generators.

The next plant to be erected on these lines was that controlled by the Consolidated Gold Fields and placed near Driehoek in the centre of the deep levels under the wing of that corporation. This supplies power to these subsidiary companies and provides lighting for the adjoining town Germiston. The present year has seen the establishment of a similar system on the East Rand Proprietary Mines. This plant is so situated and constructed that it can be, without interfering with the working, doubled or even trebled. Twelve boilers have been erected and the water, prior to being fed into these, is heated in the economiser. The engine room is furnished with Bellis and Morcom's triple expansion vertical engines which drive the three generators, each of which is 1000 kw. capacity. Belt conveyors and trippers are used for transferring the coal from the trucks to the bunkers and hand-filling is adopted in firing. The ashes are emptied on to an iron belt conveyor and discharged outside the building. Two "Sturtevant" fans have been erected for induced draught purposes.

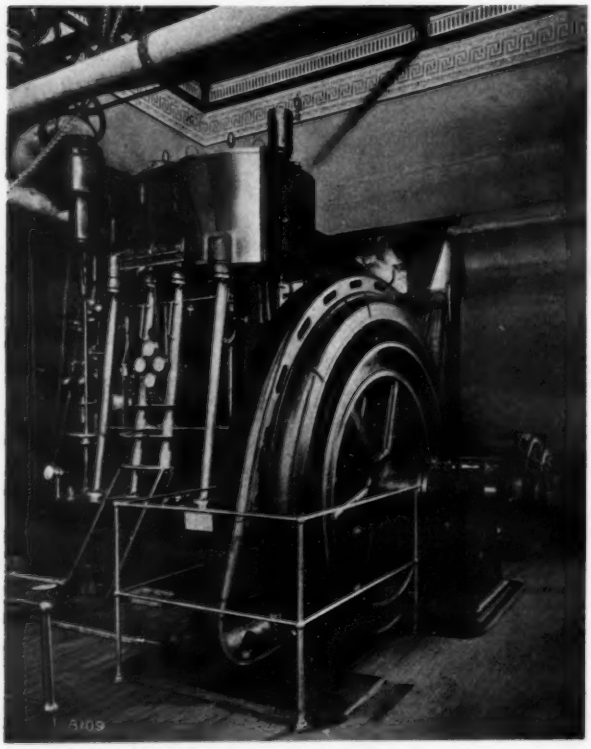
Another new plant started at the beginning of the year is that of the Premier Diamond Company. Here a duplicate set of triple-expansion verticle marine type engines of 1,500 i.h.p., made by Fullerton, Hodgert and Barclay, forms the motive power. The condensing plant for these engines is of the Mirlees-Watson make. Crompton dynamos worked by Bellis-Morcom engines supply power for the electric lighting, whilst the boiler house consists of six Babcock and Wilcox boilers fed by Weir pumps.

Water Softeners.—In this connection it may be noted that there is a felt want for a really reliable water purifier. The

mine water is in most instances totally unfit for boiler purposes, whilst the town supply forms a heavy item against working expenses. The following notes on a mine water from a Central Rand mine sufficiently justifies some scheme for its purification.

		Grains per gal.
Acidity (free, expressed as sulphuric acid)		4 26
Total sulphates (free, expressed as sulphuric acid)		32·80
Total solid residue		78 20
,, ,, ,, after ignition ...		58 20
Hardness	Temporary 13·6 deg. (Clark's).	
	Permanent 35·6 ,, ,,	

Purifiers guaranteed to render such a water fit for use and of sizes varying from a capacity of 500 to 9,000 gals. per hour are badly needed. Most of those at present in use here are liable to get out of order too easily, and the boilers and tubes suffer.

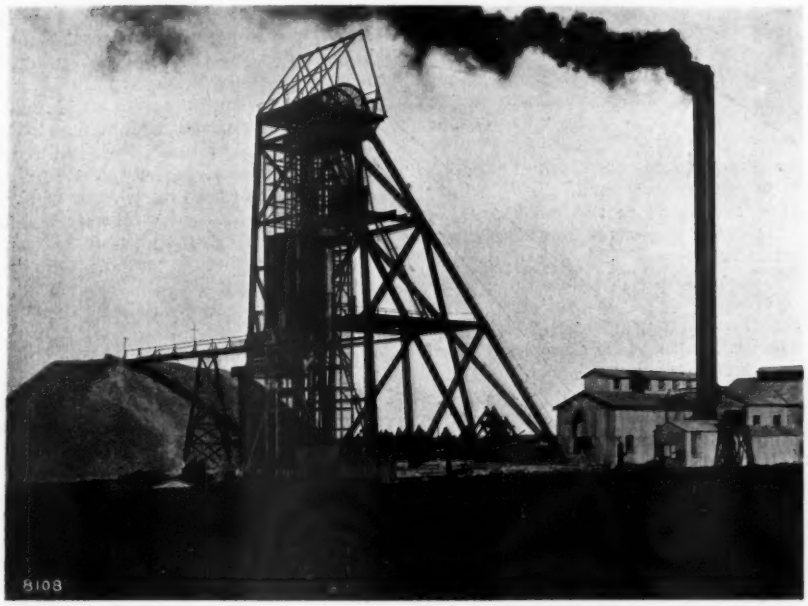


250 KW. 3-PHASE ENGINE AND GENERATOR. NEW GOCH, G. M. CO. LTD.

Producer gas engines have not as yet found great favour on the Rand. For this the vexatious delays and the intermittent running of the large plant at the Johannesburg Power Station may be held to be not a little liable. This embodies the largest electric and gas producer machinery units hitherto erected, but a detailed description would be out of place here. A small suction gas producer plant, the first to be erected on these fields, has been put up at Springs on behalf of the Rand Water Board.

Headgears.—Of late years steel headgears are more in vogue than wooden erections, though, of course, each has its advocates. These for the deeper levels are from 90 to 120 ft. in height. The photo on page 389 gives a clear illustration of the design in general use. The engine rooms attached to the headgears contain the greatest divergencies of any machinery on the Rand.

Winding Engines.—One of the most modern of winding engines is that lately erected at the Hercules mine. It is anticipated that the reef will here be struck about 4,000 ft. vertical and two permanent sinking engines by Robey & Co., of Lincoln, have been erected to sink to this depth and carry on the initial development work. They are of the coupled horizontal geared type,



DEEP LEVEL STEEL HEADGEAR AND ENGINE HOUSE.

having cylinders 16¼ ins. by 33 ins. They are fitted with patent drop valve gear, which can be so easily reversed by hand that no steam gear is required for that purpose. The drums and gearing are all of steel, the former being 8 ft. in diameter by 3 ft. 6 ins. in width. Powerful post brakes of the floating type operated by steam are fitted to the drums, and disc brakes are also provided.

A direct-acting winding engine is also being installed by this same firm on the Simmer and Jack East Gold Mine. In this type the drums are carried on the crank shaft itself. The cylinders are 20 ins. diameter and 48 ins. stroke. Governors control the speed of the engine and consequently the speed of the winding ropes. The crank discs are also fitted with brakes operated by foot lever on the driver's platform.

On the East Rand Proprietary Mines conical cylindrical winding drums are attached to the Hicks - Hargreaves engines. These are of the latest pattern and are in all probability the largest in use on any gold field. The conical portion is 12 ft. in diameter at the narrow end, and a spiral groove extends up to the cylindrical portion, which is 20 ft. in diameter. The end of the rope is attached to the narrow part so that the greatest strain is taken where the engine has most power. A "Bayley" recorder registers the depth of the skip at any point and the speed at which it is travelling.

Winding Ropes.—Since the accident at the Robinson Deep over two years ago when a flat rope broke, thereby causing the death of some 40 natives travelling in the skip, great attention has been paid to the proper installation of wire ropes and the care of these. Taper ropes have not come into general use, but it is intended to introduce these with the new cylindro-conical drums to be erected on the Jupiter and Simmer and West mines, the former having the

deepest shaft along the Rand. At present a Government Commission is sitting, the object of whose researches is to ascertain the best conditions under which sinking can be carried out, the determination of the factor of safety for ropes in use, and to obtain some safety catch which might be recommended for use on deep level shafts. Working models are made of the most suitable of the designs sent in and these are practically tested on the disused Marcus vertical shaft at the Langlaagte Estate.

So far nothing very startling has been discovered. Most of the appliances fail when put to the actual test, and only one has up till now satisfied the three tests. These tests are (a) releasing the skip with no initial velocity; (b) delaying the action of the catches until the cage has fallen three feet; and (c) lowering the cage as fast as possible for 30 ft., when a slip hook disconnects the rope. The "Garvin" safety appliance fulfilled all these tests, but the shock produced by the sudden stop is very great, and some modification would be necessary to reduce this. The device consists of mild steel wedges with teeth $\frac{1}{2}$ in. in pitch and $\frac{1}{4}$ to $\frac{3}{4}$ in. depth, which engage with the sides of the timber guides. The wedges are operated by means of toggle arms, which push them into position as soon as the weight is taken off the rope.

Electric Hoists.—Electric hoists have made but little headway on the Rand. The most modern is that which has this year been installed at the Village Main Reef. This has been designed to haul eight tons of rock at a speed of 1,500 ft. per min. The General Mining and Finance Corporation have electric hoists at work on several of their mines, some of them having been in use for two or three years.

Ere leaving this subject, it may be interesting to note the results obtained from a test on a twin tandem compound condensing winder during a fixed period of time to determine the steam consumption. The test was carried out under ordinary working conditions during the hoisting of ore from a vertical deep level shaft over a period of 7 hrs. 5 mins., when 1,542,213 lbs. of ore were hauled from a depth of 2,290 ft. The average steam consumption per hr. amounted to 6,434 lbs., or per shaft h.p. hr. 25·5 lbs., or per i.h.p. hr. 21·7 lbs., whilst the mechanical efficiency of the hoisting apparatus is given at 85 per cent. A Weir meter installed to register the same results gave very approximate figures over a lengthened period. One particular brought to notice by the latter instrument shows that during the special test the actual running time of the skip was 66 per cent. of the possible, whereas the weir meter indicated that under ordinary running, that is over 24 hrs., scarcely half that percentage was obtained.

Underground Mechanics. — The chief difficulties tackled of late underground have been the mechanical conveyance of the broken ore by chutes (shaking) over the flat stopes to the boxes and the transference thence to the stations, and some sort of appliance for minimising the dust caused by machine drills in drives, winzes and raises. Spraying apparatus has been attached to the machines, but these have found little favour amongst miners, the accompanying dampness militating as much against their health as the dust. There are at present working on the Rand mines over 2,200 rock drills, and this number is gradually being increased. Hence a big demand for high-class steel for drills exists.

An overhead mono-rail for transferring the loaded truck from the ends of drives or from stope boxes to the grizzly at the shaft station has been installed at the Langlaagte Deep, and an extended run has proved the system to be labour saving, speedy and economical. The drives are all inclined slightly towards the shaft, so that the full truck requires very little motive power, human or animal, to propel it.

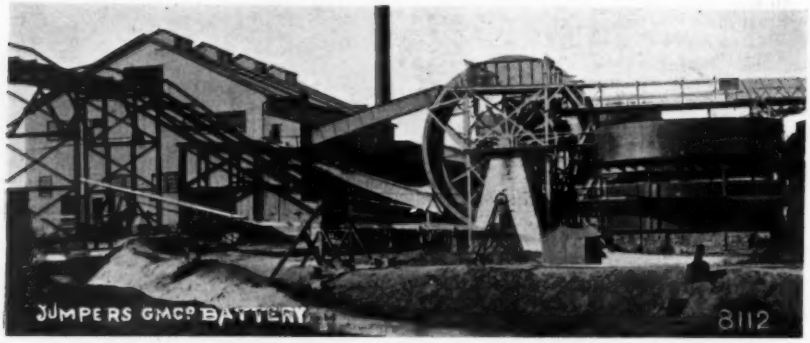
An important improvement in vertical shaft sinking is being introduced at the Kleinfontein Deep. This company has but recently placed orders for four

high-lift centrifugal pumps, to be driven direct by electric motors. Each of these pumps will require to raise 10,000 gals. per hour with a head of 1,540 ft. This will be the largest electrical centrifugal pumping installation on these fields, each pump having a motor of 140 b.h.p. at a pressure of 2,000 volts. Electric pumps are gradually displacing the old Cornish pumps for underground shaft work, and quite recently some five and a half miles of insulated cables were ordered for the underground equipment of certain of the Rand Mines group.

HERCULES DEEP LEVEL WINDING ENGINE.

Conveyor Belts.—Turning now to the reduction plant we find improvements going on continually. There is little finality on the Rand, and every new plant has invariably some fresh mechanical feature lending itself to the better extraction of the gold or the cheapening thereof. Owing to the unskilled labour difficulty, engineers have been forced to exert their utmost capacities to the solution of the transferring of the ore, and we find this point carried almost to a fine art on the new mills at the East Rand Proprietary Mines. After being discharged into the bins at each station underground, the ore is automatically conveyed, crushed, treated and dumped, without hand labour being brought into requisition.

Belt conveyors have now been installed in all the best equipped mines, and at the present time there are close upon twenty miles of these in use along the reef, whilst a considerable quantity more is on order. A brief description of the arrangements on the Angelo reduction works will give a general idea of the practice existing on modern equipments. The ore from the mine is tipped on to grizzlies which separate the fines from the coarse ore. The fines are immediately discharged on the



JUMPERS BATTERY, TAILINGS WHEEL AND DOUBLE DECK CYANIDE PLANT.

travelling belt, which conveys them to the battery bins. The coarse pieces on the other hand are led to large crushers and there broken into pieces of a certain size, whence they are brought by belt to the sorting station. Here workmen sort out the waste from the banket. The former they drop into bins beneath their feet, and these receptacles are emptied automatically by chutes, and the waste rock conveyed by trucks to the waste dump. The ore travels onward and drops into crushers (Blake Marsden type), which reduce it to a size fit for feeding into the stamp batteries.

The discharge from these crushers falls on to the main mill belt, which, ere it reaches the mill, has its contents automatically weighed on a "Dennison" continuous weigher. This machine has now become very popular on the mines, as it supplies a long felt want. Prior to its introduction the ore was weighed in trucks between the crusher house and the mill, an average number of trucks being weighed and tally kept of the trucks entering the mill. This involved a certain amount of labour and supervision, but the "Dennison" weigher not only weighs but accurately records the weight of the ore passing over the belt during any fixed period. Thus the vexed question of mill tonnage is solved and the value of the ore treated can be more accurately determined. The ore is led up this inclined belt to the bins, into which it is distributed by an automatic travelling shuttle belt. This latter arrangement has been here introduced with great success, and already modifications on the same lines have been talked about.

The Battery.—The mill consists of 220 stamps placed back to back, 110 stamps with their tables, &c., facing one side and 110 facing the other way. This was one of the first mills to adopt electricity for the driving of the cam shaft. There are two "A. E. G." motors, one at each end of the mill, and each is capable of 400 k.w. These are connected to the main shaft by Zodel Voith's flexible couplings, the aim being to prevent as far as possible any vibration travelling to the motor. This main shaft passes through the centre of the building between the two sets of batteries, and from it each individual cam shaft is driven. "Seymour" clutches are used here, and the cam shafts are connected to the main shafts by a pulley which is placed in the centre of the cam shaft, the endeavour being to prevent all the pull on the shaft being at the one end. Each head of ten stamps is anchored to one anvil block, but the cam shaft connects the five at the one end with the five at the near end of the adjoining anvil.

The central supports of the mill are 16 ins. by 14 ins., whilst the foundations are of solid stone and concrete 8 ft. in depth. Laid on this is a layer of about

14 ins. of timber, on which rests the anvil blocks, tie bolts holding the anvils and mortar boxes in position. "Hunter" feeders have been installed here, but have not given the satisfaction hoped for, and it is not unlikely that in the near future "Challenge" feeders will replace them. Two jets of water supply each five stamps, though the latest practice, as shown on the Linpard's Vlei Estate Gold Mine is to have jets of water playing on each stamp. When fine crushing is wanted the water enters the box close to the die, but for coarser crushing the water discharges at the top in the usual manner.

Labour saving devices are in existence for the handling of cam shafts, stems, shoes, dies, and even mortar boxes. A light travelling crane runs along the front of the boxes for expediting the removal of the former, whilst a heavier one is in existence for shifting the boxes. These deliver on to another similar crane at the end of the mill and this transfers the broken part to a workshop adjoining. The stamps themselves aggregate each 1,350 lb. in weight, though the Linpard's Vlei plant improves on this also by using 1,550 lb. stamps. On the latter plant the stems are 4 in. in diameter set to 10½-in. centres, the shoes 14½ in., the dies 8 in., and the heads 24 in. deep.

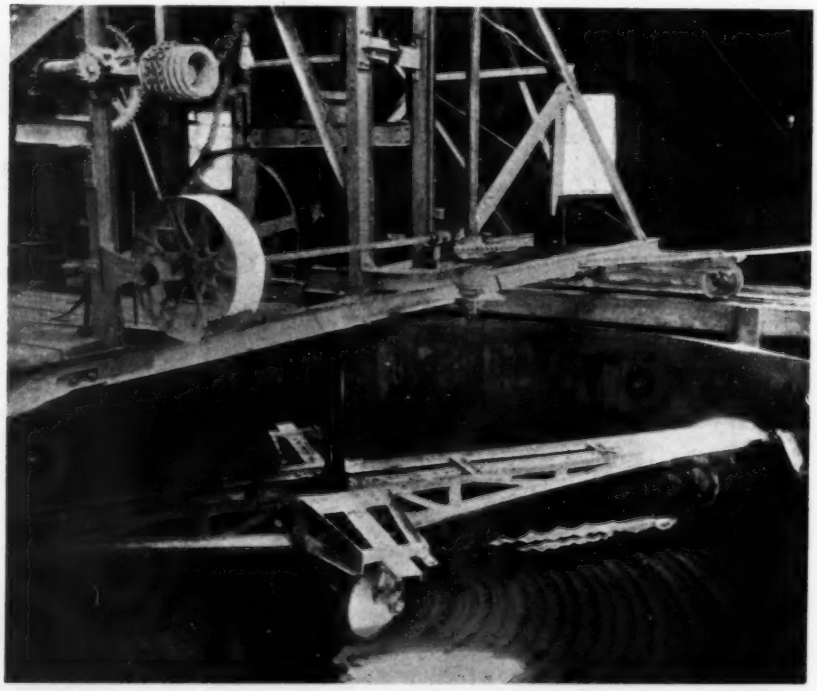
A new feature has been introduced at the Angelo by having the amalgamating tables capable of sliding back from the mortar boxes so as to enable the workman to get at the boxes. He can thus clean them out more thoroughly and has more command over the broken or worn shoes, dies or other machinery requiring replacing. There is practically no vibration of the table and no cutting of the plate as the joint is well beneath the sill and blanketting prevents leakage. Adjustable tie clutches keep the table in position when in use.

"Wilfley" Tables.—In this mill there has been introduced for the first time

BELT CONVEYOR AND DISTRIBUTING ARMS AT KNIGHTS DEEP CYANIDE PLANT.

here a complete series of "Wilfley" tables. These take the whole product from the stamps and classify this into concentrates or the heavier and richer portion, sands and slimes. The concentrates are raised by bucket elevators for delivery to the tube mills for regrinding, as in this way the gold is more easily got at. These tube mills have been placed on almost all the up-to-date reduction plants. In Australian and American practice the object is to slime the ore, that is, to grind it into an impalpable powder, but on the Rand the work of the tube mill is to reduce the size of the sands or concentrates. Thus, here the wear and tear on the liners and pebbles is much more severe, and a considerable expense is entailed monthly in upkeep. The liners found of most advantage are "silex" or quartz blocks, but there is little doubt that some other grinding medium will replace the tube mill, some instrument cheaper to instal and to work. The wheeler pan has as yet found little favour, though orders have recently been placed for their erection on several of the mines.

"Pohlé" Lift.—A new feature in the shape of the "Pohlé" lift has been brought into play in the raising of the sands plus the reground concentrates to a height of 55 ft. The general practice has been to elevate these by means of tailings wheels, but it is maintained that the initial expense of erecting the "Pohlé" lift is less, and given a 25—30 per cent. efficiency the working expenses should be about the same. It is doubtful, however, if this efficiency can be attained, a figure slightly under 20 per cent. being more probable. The "Pohlé"



BLAISDELL EXCAVATOR AT WORK.

lift consists of a well, 90 ft. in depth, which in this case has been concreted and into which the pulp flows. Two pipes are fixed in this, the larger one about 8 ins. inside diameter being used for discharging the pulp, and the smaller one about 2 ins. internal diameter conducting the compressed air. At or near the bottom of the well the smaller pipe joins the larger one, and the compressed air from it enters the eduction pipe and forces the pulp from the exit at the top.

There are two theories regarding the action that takes place. One is that the combination of air bubbles and water being lighter than water, rises and is discharged. The more feasible theory, especially when a large eduction pipe is in use, is that the compressed air causes piston-like layers of pulp and air alternately to be formed, and the latter being still under compression forces the water upwards. The discharge pipe is lined with wood to prevent abrasion of the pipe by the sand.

Sands Excavators.—In cyanide plants labour-saving devices are ousting the hand labour of the Kaffir. By the use of the "Blaisdell" excavator and distributor, not only is hand labour lessened, but the extraction of the precious metal is improved by the breaking up of the unevenly mixed product obtained in settling the sandy part of the mill production on account of the better leaching and æration obtained. In this way, exceptionally favourable extractions are being obtained and there seems a big future for these installations. The system followed is the breaking up of the sands, which have been collected in the tank, by means of rotary blades. These loosen the packed sands so that they fall through a bottom discharge door on to a conveyor belt. This carries the sand to another tank where a distributing apparatus scatters it in extremely fine form over the leaching vat.

After the gold has been extracted from the sands by the cyanide solution the residue sands are again discharged on to a belt conveyor, and this carries them to the dump, where a movable distributing arm carries the sand to a point beyond the edge of the dump and discharges it, the arm being shifted only as occasion requires. The accompanying photograph shows such an arrangement as installed by the Consolidated Gold Fields engineers on the Knights Deep.

Filter Presses.—Filter presses also take their place for purifying gold slimes solution in the cyanide works, but there is every probability that an enlarged field is opening out before them. Five-ton capacity presses have been introduced on General Mining mines for the separation of the gold bearing solutions from the unleachable slimes. The accumulator on the Meyer and Charlton is weighted up to about 2,240 lbs. to the sq. in., which gives an effective pressure on the hydraulic rams, equivalent to a pump filling the presses at a pressure of slightly under 90 lbs. The discharged cake of slimes contains 26 per cent. of moisture instead of 55 to 45 per cent., as obtained by the ordinary settlement process.

Imports for the Mines.—For the first six months of the past year the imports in the engineering line for the Transvaal have been declared at the following valuation :—

	£
Cement	16,925
Iron and steel—	
Pipes	156,314
Sheet Iron	10,345
Corrugated Iron ...	62,988
Machinery—	
Electrical	86,546
Mining	349,426
Other (non-agricultural)	395,616
Wood—	
Unmanufactured ...	130,707
Manufactured	58,360

Fortunately in the interests of the mining industry, the spirit of economy has gained many adherents in the past year, with the result that repairing orders are now more frequent, and in addition, mining and mechanical engineers are enquiring more closely into the quality of the goods supplied. The tendency now seems to be to purchase on the quality instead of, as previously only too frequently occurred, giving the order to the lowest tenderer.

Summing up these it may be said that the mining industries of the Transvaal open up for the engineer a wonderful and varied arena for the exercise of his fullest abilities. The future of the community and of the mines depends on his solving the many mechanical problems which will tend to mitigate the unskilled labour problem, and success can only be attained by diligent and persevering research. Strides in the right direction have been made within the past four years, but much more remains to be done.

Mechanical Canal Locks in Canada.

THE larger of the two Canadian hydraulic locks is situated on the Trent Canal, within the limits of the corporation of Peterborough, and has been in operation for the past two seasons. The other lock, near the village of Kirkfield, is practically completed in a stretch of canal joining Balsam Lake and Lake Simcoe.

The hydraulic lock is theoretically an automatic machine, and is designed to take the place of ordinary locks where a great difference of level is found in a short distance. Besides the Peterborough lock, there are three other locks of this type in operation, one being in England, another in Belgium, and the third in France.

In principle, the hydraulic lock may be likened to two immense hydraulic elevators of the simple plunger type, having their presses connected together so that the descent of the one causes the rise of the other. In place of the ordinary elevator platform we have a large water-tight box or tank closed at either end by a gate. The lockage is performed by towing the vessel into this box of water and then closing the gate on the end of the box as well as that of the canal, thus leaving the box independent of the reach and free to move vertically. The box with the water and the floating vessel is then raised or lowered to the other reach. The chamber or box about to descend is loaded with a few more inches of water than the other chamber, thus giving it the necessary additional load or "surcharge" to enable it to cause the ascent of the other when water communication is established between the two presses. The construction of the Canadian locks varies materially from those of Europe, and as far as outward appearance goes there is little similarity. The departures are largely due to the climatic conditions and to the different practices adopted by American and European engineers in steel construction. The wells in which the large presses stand were excavated about 75 ft. below the floor of the pits, the diameter of the rock excavation being 16 ft. 6 in. The substructure of the lock is built entirely of concrete, and contains a little over 26,000 cubic yards. The breast wall is 40 ft. thick, and about 80 ft. high, the length being 126 ft. at the base.

The main presses form the most interesting as well as the most important part of the whole structure. It is thought that they are the largest hydraulic presses that have ever been made. Each ram is 90 in. external finished diameter, and has a working stroke of 65 ft. The gauge pressure in the presses during operation is very nearly 600 lbs. per square inch. The inside diameter of the press is 7 ft. 8¼ in., giving a water space of 1¼ in. all round between the ram and the press.

The pipe connecting the presses near the top, immediately below the stuffing boxes, is a heavy, wrought-iron pipe, 12 in. in diameter, and ½ in. thick. Through this pipe all the water displaced by a descending ram is driven into the other press, causing its ram to rise. Midway between the presses, a gate valve is placed in the 12 in. pipe, controlled solely by the lockmaster in his cabin on the top of the middle tower.

The towers, three in number, are on the same transverse centre line as the wells. In round numbers, the total height of each tower from rock bottom to the top is 100 ft. The lower gateways extend from rock bottom to the top of the side wall, and are built to accommodate the steel gates which closes the ends of the lower reach. In the centre wall between the gates is a small room which contains the gate-operating machinery. Each lock chamber is 139 ft. by 33 ft. with 9 ft. 10 in of plating on the sides, and the load of water which each of the lock chambers contains is 1,700 tons.

The trusses which carry the load of the chamber are double cantilevers, having curved top and bottom chords. The depth of the trusses at the centre is 32 ft., this depth having been chosen with a view to preventing teetering.

The record lockage, so far, at the Peterborough lock is 6½ minutes, being the whole time from the stopping of the vessel in the lower reach to her proceeding on her journey under her own steam in the upper one.

The Connaught Bridge, Natal.

Summary.—This bridge carries the North Coast main road over the Umgeni river at a point four miles from Durban and three and a-half from the Indian Ocean. It is the largest road wagon bridge in the colony, and with the exception of the railway bridge across the Umhloti river at Verulam, the only cylinder bridge in Natal.

The bridge has twelve spans, the two end spans being 74 ft. 8 in., and the others 77 ft. 4 in. from centre to centre of piers. The total length from abutment to abutment is 922 ft. 8 in., and the height over river bed is 37 ft. The carriageway is 22 ft. wide, and there is a footway 4 ft 6 in. wide outside the main girders on each side of the bridge, carried on brackets.

The abutment on the south or Durban side is of concrete, with masonry facing and masonry parapet walls. This abutment is founded on 12 in. by 12 in. pitch pine piles, driven about 25 ft., the heads being braced together and surrounded 6 ft. deep with concrete. The abutment on the north side is composed of a pair of cylinders, as no suitable bottom was found for a concrete abutment.

The embankment for the approach road is carried round the cylinders and faced with masonry pitching.

The piers are of steel cylinders 6 ft. diameter below river bed, and 4 ft. diameter above river bed, and each pair of cylinders is braced together to form the pier. It was found necessary to sink the cylinders to a bed of sea sand, at an average depth of 77 ft. below river bed, the greatest depth being 104 ft. The entire length of cylinders are filled up with concrete, upon which the bed-plates rest.

The main girders are of N type, and carry steel plate cross girders and corrugated decking. The roadway throughout is macadam.

The weight of steel-work in the piers is 480 tons, and in the superstructure 850 tons. The weight of concrete in cylinders is 3,200 tons.

The erection was commenced in February, 1904, and the bridge was opened for traffic on 10th January, 1906.

The steel-work was made in England by Messrs. J. Westwood & Co., London, from designs of the consulting Engineer to the Natal Government, Mr. H. G. Humby, M.Inst.C.E. The erection of the bridge was carried out for the Public Works Department by Messrs. Smullins Bros., & Mansel, contractors, Durban, the resident engineer for the Public Works Department being Mr. Edward John Stead, who presented the following interesting description of the work at the March meeting of the Society of Engineers.

THE new structure replaces an old low level timber bridge situated immediately on the upstream side, which was erected in 1868 by the Imperial Military Authorities. The area of the watershed of the Umgeni river above the bridge is 1,660 square miles and the length of the river is 165 miles. The source of the river is near Spioen Kop and the Inhluzane Mountain, 6,200 ft. above sea level. There are two vertical falls in the river, Howick Falls and Albert Falls, together amounting to 380 ft. Allowing for these falls, the average grade of the river is about 27 ft. per mile, or 1 in 195.

Rainfall.—From observations of rainfall during the last 10 years, extraordinary rainfall seems to be confined to the coastal district, comprising about 130 square miles of the watershed. In that area 6 in. of rain fell in 3 hours on May 31, 1905, *i.e.*, 2 in. per hour. Inland such heavy falls are not recorded within the last 10 years. The discharge at the bridge, due to an assumed maximum rainfall of 2 in. per hour, due to the coastal area of 130 square miles, would equal 10,000,000 cubic ft. per minute, and it is possible that this discharge could occur in about 2 hours after the commencement of the rain. The whole watershed could be in operation in from 16 to 20 hours, assuming the velocity of the flooded river to be about 10 miles per hour. The discharge at the bridge due to an assumed maximum rainfall of 6 in. per 24 hours, or ¼ in. per hour, would equal 15,500,000 cubic ft. per minute, making no allowance for loss by percolation.

The highest known flood level, that of 1856, is 27·10 ft. above sea level datum, and the area of the cross section of the river up to that level is 15,500 sq. ft. At a velocity of 10 miles per hour, which was the velocity observed during an extraordinary flood in June, 1905, the discharge at the bridge would be about 13,700,000 cubic ft. per minute. The level of the bottom boom of girders is 29·47 feet above datum, but flood water could never reach higher than 28·77, when it would flow over the approach roads

and expend itself over an enormously increased area.

General Description.—The bridge consists of twelve spans (Fig. 1), the total length between abutments being 922 ft. 8 in. Each end span is 74 ft. 8 in. from the face of abutment to the centre of pier, and the other ten spans are 77 ft. 4 in. from centre to centre of the piers, or 73 ft. 4 in. in the clear. The girder bed level is 22·32 ft. above winter level of river, and 2·37 ft. above the highest known flood level. The abutment at the south or Durban end is built of concrete with a masonry facing, on a piled foundation, and the abutment at the north or Zululand end consists of a pair of cylinders, similar to the piers, with the embankment carried round them and faced with dry masonry pitching. Owing to the soft nature of the underlying strata it was not deemed advisable, nor was it reasonably practicable, to construct a concrete abutment on this side. Each pier is constructed of a pair of steel cylinders 25 ft. 6 in. from centre to centre, sunk to a suitable foundation, and then filled up solid with concrete. The cylinders are 6 ft. in diameter below the river bed and 4 ft. diameter for the upper portion. The two cylinders are braced together to form one pier, and fitted with ornamental cast-iron caps.

The superstructure is of steel throughout. The main longitudinal girders are 7 ft. 9 in. in height, of the N type, ten bays to each span, the four centre bays being counter-braced. Each span of main girders carries eleven cross girders 2 ft. 6 in. deep, resting on and riveted to the lower booms. On the top of the cross girders corrugated flooring plates are riveted, the troughs of which are filled up with broken stone and asphalt. The whole floor is covered with a layer of broken stone and asphalt, upon which is the macadamised road surface. Footways 4 ft. 4 in. wide are provided on each side of the bridge outside the main girders. The approach roads are of easy gradients, and 35 ft. wide.

South Abutment.—The preliminary probings taken over the site of the south abutment indicated a bed of hard clay at a depth of 28 ft. below ground level, upon which it was intended to commence concreting. However, in getting out the excavation difficulties were experienced in dealing with the water directly the level of the river bed was reached, *i.e.*, 10 ft. below ground level. The strata was so pervious that a very large quantity of water poured in. Two steam pumps, a 3-in. pulsometer, and a 5-in. centrifugal, were tried, but were found to be ineffective. An 8-in. centrifugal steam pumping plant was then utilised, and with that a depth of 15 feet from ground level was reached. Tube borings 3 in. diameter were then taken at several points in the excavation, and after passing through layers of sand and soft clay a hard blue gravel bottom was reached at a depth of 37 feet below ground level. The obvious difficulty, danger, and expense of having to carry an open excavation to such a depth through the unsatisfactory strata shown, caused a reconsideration of the design for this abutment, resulting in the adoption of piling.

There are seventy-five piles (Fig. 4) 12 in. by 12 in. pitch pine, the average length being 29 ft. The heads of the piles are braced together longitudinally and transversely with 12 in. by 6 in. pitch pine walings, and cross heads bolted with 1-in. diameter wrought-iron bolts. The piles were driven with a 1-ton hammer with an average drop of 7 ft. Two piling engines were worked at the same time, in one case a comparatively light guiding frame was utilised in conjunction with a 3-ton crane and a steam winch. The jib of the crane was stationed immediately over the head of the pile, the strain of raising the hammer being borne by the crane, the frame only serving to guide the pile. The wire rope from the winch passed through a block at the foot of the crane, thence up the mast and to the jib and hammer. The other frame was of heavier construction, as no crane was used; the wire rope passed from the winch through a block at the foot of the ladder, thence over a pulley in the frame head. Both arrangements were effective and expeditious, though the lighter frame was the more easily moved from place to place, and the crane had only to be swung over each pile and stationed there by means of guy ropes. Piling was commenced on May 5, 1904, and completed on June 2, 1904, being 24 working days, giving practically three piles driven per day. The penetration of the piles at the last blows of the hammer varied from $\frac{1}{8}$ in. to $\frac{1}{4}$ in., with a drop of 7 ft. All the piles were cut off 1 foot above the level of the water, so as to allow the walings and cross heads to be fitted.

There was a depth of 5 ft. of water in the excavation, and as the inflow was very heavy, pumping could not be carried on during any concrete work, so the concrete was placed under water by means of a bell-mouthed wooden shoot, 7 ft. deep, made to go between the rows of piles. The shoot was hung on to the crane rope and lowered

to the bottom of the excavation. The concrete was mixed in a "Ransome" drum mixer, tipped out on to a platform and left until it was in a semi-plastic state. This was done in order that the concrete should not be damaged in passing it through the water in the shoot. The shoot was filled up and constantly kept full so that the concrete was not tipped through water. By slightly lifting the shoot with the crane and rocking it a little, the concrete flowed out quietly and steadily and with a minimum disturbance of the cement. Concrete was filled in for the full width and length of the excavation and carried up to a height of 6 ft. above the pile heads. Upon this foundation the abutments and wing walls were built of concrete, with rock-faced free-stone masonry faces averaging 18 in. on the bed. A section of the abutment is shown in Fig. 5. From the top of the concrete foundation to the level of the weep-holes, well-tempered clay puddle was placed with falls leading to the weep-holes, and above the puddle dry stone lining was carried to the top of the abutment. The girder bed-stones are of red Natal granite from the Alexandra Junction granite quarries, which are situate some 30 miles south of Durban. The concrete throughout was composed of 6 parts of broken whinstone, 2-in. gauge, 3 parts of coarse sand from the Umgeni river bed at the bridge, and 1 part Portland cement.

The string courses, parapet walls, and pilasters, are all of rock-faced freestone masonry, obtained from the Mount Moreland quarries, 20 miles north of Durban. At the girder ends, small piers, 2 ft. by 1 ft. 3 in., with caps, the underside of which are level with the tops of the girders, are designed to give a finished appearance, and between these small piers and the parapet walls are the entrances to the bridge footways. The caps on the small piers have white marble inscription tablets let into them, giving the name, dates, cost, &c., of the bridge.

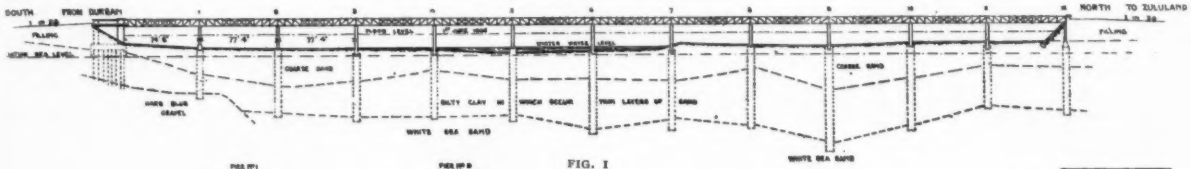


FIG. 1

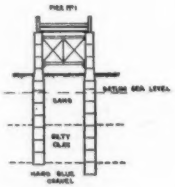


FIG. 2.

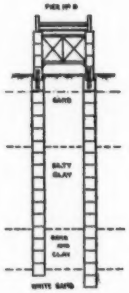


FIG. 3.

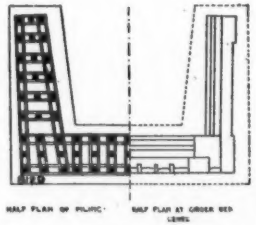


FIG. 4

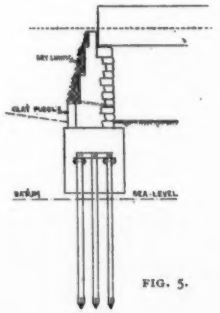


FIG. 5.

CONNAUGHT BRIDGE, NATAL.

The weight of the abutments and wing walls, &c., is 1,500 tons, and, with the load of half a span imposed by the girders, and the live load on half a span, the total weight brought to bear on the foundation is 1,628 tons. The base area of the concrete foundation is 1,000 sq. ft., and the safe load for the material upon which it is built may be assumed at 0·75 of a ton per sq. ft.—that is, 750 tons, leaving 878 tons to be carried by the piles, or 11½ tons per pile. Taking the *Engineering News* formula, $L = \frac{2wh}{S+1}$, where L equals safe load in tons, w = weight of hammer in tons, h = fall of hammer in feet, and S = penetration of pile in inches at the last blow, the safe load per pile works out at nearly 14 tons. The formula allows a factor of safety of 6.

Cylinder Piers.—The piers are composed of steel cylinders, 6 ft. in diameter below river bed, and 4 ft. diameter for the upper parts. The cylinders were made in three segments, with vertical angles 2½ in. by 2½ in. by ⅜ in., for riveting the segments together. The tops and bottoms are fitted with similar angles for bolting the successive lengths together with ¾-in. bolts, 6 in. pitch. The skin-plates are ⅜ in. thick. The 6-ft. diameter lengths are stiffened by a 5 in. by 2½ in. by ⅝ in. horizontal tee in the centre of the cylinder, and the 4 ft. diameter lengths by a 2½ in. by 2½ in. by ⅜ in. angle in a similar position. The bottom lengths of the 6-ft. diameter cylinders have a ⅜ in. by 12 in. cutting-plate riveted on to the outside of the skin plate, and these lengths are further stiffened by three 5 in. by 2½ in. by ⅜ in. tee vertically up the lower half. Details of the cylinders are shown in Fig. 6. The top lengths of the 4-ft. diameter cylinders are fitted with a 4½ in. by 4½ in. by ½ in. angle outside, to which a moulded cast-iron cap is fixed by means of tap bolts. The rivets on the outside of all cylinders are countersunk. All the cylinders were shipped from England in three segments, and riveted together on the works.

The design provided for a 6 ft. length of cylinder tapering from 6 ft. to 4 ft. diameter to form a connection between the different diameters of cylinders forming the pier, the level of the bottom of the taper pieces being about 2 ft. below river bed level, and this level had to be adhered to. In the construction, however, it was found that it would be difficult and expensive to sink the 6 ft. diameter cylinders to the exact levels to receive the taper pieces, or to adopt the only other alternative which appeared to be practicable, that is to obtain making-up pieces of cylinder, which would necessarily have to be obtained locally owing to the exact length required being indeterminable until the sinking of the cylinder was completed. In the first pier, when the cylinder was satisfactorily berthed on hard gravel, it was found that there was a space of 3 ft. 4½ in. between the cylinder and the taper piece level, the top of the cylinder being 2 ft. under water. At this stage the practical difficulty of using taper pieces had to be faced, and it was carefully considered by the engineers of the department. It was decided that it would not be advisable to attempt to sink the cylinders to the exact required depth to allow the taper piece to be fixed at its correct level. The level of the taper piece could not be altered owing to the position of the bracing of the piers, as will be seen by Fig. 2. It was therefore decided that making-up pieces of the exact lengths should be obtained locally, and fixed on the cylinder, and upon these the taper pieces were set. The cost of making-up pieces obtained in the colony was nearly 100 per cent. higher than that of similar work imported from England. Time would not permit of the making-up pieces being made in England, and so the extra expense was unavoidable. Further, considerable difficulty was experienced in fixing the making-up pieces below water.

The experience gained in the first pier gave rise to the consideration of an alternative method of connecting the cylinders of different diameters, and the author proposed a form of telescopic joint, which was ultimately adopted on all other piers. In this design the 4 ft. diameter cylinder is telescoped into the 6 ft. diameter cylinder as much as is necessary to meet the levels, but not less in any case than 2 ft. The cylinders are filled solid from top to bottom with concrete, and in the concrete are embedded three railway rails about 10 ft. long, as shown in Fig. 3. An advantage of this joint is that any slight departure during sinking from the true position can be rectified when placing the lesser diameter cylinder, and perfect alignment assured. Practical demonstration of the strength of the joint was afforded during the heavy flood of 1st June, 1905, when the bridge was constructed only as far as pier No. 5. The flood brought down an enormous amount of *débris* which accumulated against the old bridge, causing it to be carried away. A large portion was dashed against pier No. 5, and turned broadside up against the pier. In that position it exerted a tremendous pressure on the pier, which showed not the least sign of failure.

Sinking Cylinders.—The staging and guides for sinking the cylinders are shown in Fig. 8.

The piles were 12 in. sq. and driven about 12 ft. below river bed. A few inches above water level a set of 6 in. by 12 in. horizontal timbers were bolted to the piles, leaving a space of 2 in. between the faces and the outside of the cylinder in order that the cylinder might be controlled by wedges. The piles were left about 9 ft. above water level, and at the top a second set of horizontal timbers were fixed. Three lengths of cylinder were bolted together, the cutting edge being placed on the river bed, and carefully plumbed up every way, then sinking commenced. The sinking plant consisted of a 3-ton steam crane, mounted on a carriage and rails to travel longitudinally, and a grab. The crane was stationed on the centre line of the bridge and behind the pier, so as to work alternately at either cylinder. Two forms of grab were used, one being Butter's hemispherical grab, opening in three parts, and one oblong grab by Stothert and Pitt, opening in two parts. Both grabs did good work, but the latter was the better in clay. The former cut from the centre of the cylinder each time forming a "nest" and leaving a ring of clay all round the inside of the cylinder, thus impeding its descent. The oblong grab did not each time excavate from the same place and consequently there was not the same liability for the cylinder hanging. As the coarse sand was excavated, the cylinder gradually sank without any load until depths from 15 to 25 ft. were reached, and in some cases until the black clay material was entered. During the initial stages of sinking, great care was exercised in keeping the cylinder in correct position and perfectly plumb. It was found that after about 30 ft. of sinking, if the cylinder was correct and plumb at that depth, it would remain so without any guides, so that the timbering was generally removed to allow greater facility in sinking.

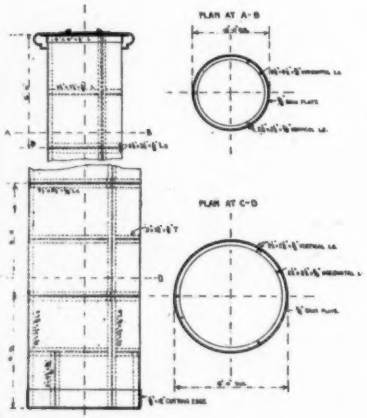


FIG. 6.

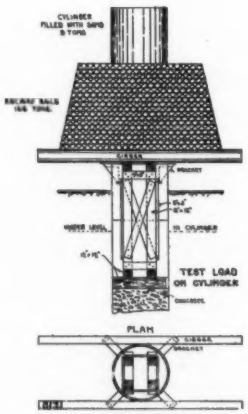


FIG. 7.

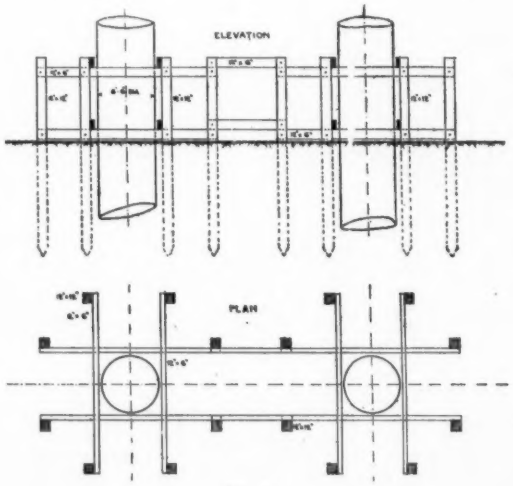


FIG. 8.

THE CONNAUGHT BRIDGE, NATAL.

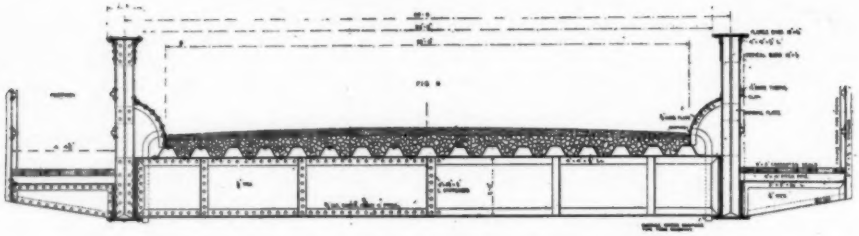


FIG. 9.—CONNAUGHT BRIDGE, NATAL : CROSS SECTION OF SUPERSTRUCTURE.

Some of the cylinders got slightly out of true position, chiefly by striking boulders. The correction for position was made in setting the 4 ft. diameter cylinders.

When loading became necessary a special length of cylinder was bolted on. This length had brackets bolted to it, and upon the brackets two of the cross girders of the superstructure were bolted down, the top flanges of the girders being made level with the top of the cylinder, as shown in Fig. 7. Upon the girders loading of railway rails, weighing 61 lb. per yard, was packed to weights required to start a downward movement. The amount of loading varied from a few tons to as much as 115 tons, and as a general rule, increased with the depth. The variations in the character and formation of the river bed and the underlying strata caused great differences in the amount of loading required. In Fig. 1, the section indicates the main beds sunk through, but the formation is alluvial and very irregular. Thin layers of clay material and decayed vegetable matter were found in the sand bed, and thin layers and pockets of sand were sunk through in the black clay bed. In some piers heavy black mud and silt were sunk through. In cases where a cylinder could not be induced to descend under a fair load, small gelignite charges were dropped to the bottom and exploded, invariably having the desired effect. Excavation and loading were proceeded with by the one crane on each cylinder of a pier alternately.

The first pier sunk was pier No. 1, and the cylinders reached a bed of hard, blue gravel at depths of 44 ft. 3 in. and 49 ft. 3 in. In order to prove that the cylinders were not just resting on a ledge of gravel a borehole was put down about 20 ft. north of the pier, and the gravel bed was found again at about the same depth. The deepest pier is No. 9, the cylinders there being 97 ft. 9 in. and 103 ft. 8 in. below river bed. The average depth of cylinders is 77 ft.

Preliminary probings had been taken over the site of each cylinder prior to the commencement of the construction of the bridge, and it was anticipated that a satisfactory foundation for the cylinders would be obtained on the clay bed at an average depth of 41 ft. When this bed was reached at pier No. 2, a test was made of its supporting power with very disappointing results. The bottom was cleaned and levelled by a diver, and a column lowered into the cylinder and stayed to the sides in such a manner that any downward movement was not impeded. The column was loaded and, with a weight equal to 2 tons per sq. ft. of area of the base, sinkage commenced, and as the load was increased, sinking was continued until the column had gone down 5 ft. into the clay, when the test was given up. Tube borings with 3-in. tubes were taken at every pier, and no practicable alternative was left but to sink the cylinders down to the white sea sand, upon which they now rest. It appears to the author that the portion of the Umgeni valley at the bridge, and for some distance inland, was at one time an arm of the sea, and that the strata overlying the white sand are all alluvial, gradually deposited by the river during a long period of years. It is interesting to note that a tooth of a hippopotamus was brought up from a cylinder when 70 ft. deep.

The sinking of the cylinders was commenced at pier No. 1 on June 6th, 1904, and a start was made at the cylinder abutment on the Zululand side on September 8th, 1904, operations being carried on from both ends, pier No. 8 being the last to be sunk. The whole of the sinking was completed on October 6th, 1905.

Surface Friction on Cylinders.—The resistance by friction on the outer skin of the cylinders was very small when sinking through the coarse sand bed, and in some cases depths of 30 ft. were reached with no load at all, the weight of the cylinder (which

at 30 ft. would be 7 tons) and excavation from the interior by the grab being sufficient to cause descent. Neglecting altogether the first 15 ft., and assuming the friction to be all caused at a depth of from 15 to 30 ft., the area of cylinder exposed to frictional resistance would be 282 sq. ft., and the resistance is 55 lbs. per sq. ft.

Upon entering the black clay bed, loading had always to be put on before any sinkage could be induced. In sinking pier No. 2 the first 30 ft. was coarse sand, and the frictional resistance occurred as just described. When the cylinder was sunk to a depth of 44 ft., that is 14 ft. into the clay, a load of 67½ tons was put on (including the weight of the cylinder), and with that load gelignite charges were required to start a downward movement. Taking the load supported by friction from the sand at 7 tons, there remains 60½ tons supported by the clay. The area exposed to the clay was 263 sq. ft., and the resistance works out at 515 lbs. per sq. ft. In the same cylinder, when it was sunk to a depth of 53 ft., that is, 23 ft. into the clay bed, the load put on was 96 tons. Again, allowing 7 tons as supported by friction from the sand, there remain 89 tons supported by the area of 432 sq. ft. in the clay, or 461 lbs. per sq. ft.

In sinking pier No. 3, when the cylinder was sunk 69 ft., the load placed on was 115 tons. The coarse sand bed was 32 ft. deep, therefore the cylinder was sunk 37 ft. into the clay bed. Allowing 55 lbs. per sq. in. for resistance by the sand at the depth from 15 to 32 ft., the weight supported is 8 tons (nearly), leaving 107 tons supported by the clay, or 345 lbs. per sq. ft. In all the foregoing calculations the resistance encountered by the cutting edge is not taken into consideration. With the exception of the figures given for the frictional resistance by sand, it should be observed that in each of the other cases gelignite charges were required to start the descent of the cylinder, and the actual resistances would be slightly higher than the figures given. The irregularities in the resistances deduced at the different depths are accounted for by the irregular and peculiar formation of the river bed previously referred to.

For guidance in sinking cylinders on similar works the author would consider the frictional resistance by coarse sand at from 50 to 60 lbs. per sq. ft. during sinking by means of excavation from the interior, and by the alluvial silty clay at from 350 to 500 lbs. per sq. ft. In cases where frictional resistance is to be

FIG. 10.—THE CONNAUGHT BRIDGE UNDER CONSTRUCTION.

FIG. 11.—ANOTHER VIEW OF THE BRIDGE UNDER CONSTRUCTION.

relied on as a means of permanent support a much higher figure could be taken for resistance by sand at depths greater than 15 ft., as it is obvious that the continual excavation from the interior destroys to a very great extent the resistance to the descent of the cylinder. In alluvial strata similar to that described, the author would not allow as a permanent support a greater resistance than from 150 to 200 lbs. per sq. ft.

Concrete Hearting and Completion of Piers.—As the sinking of each pier was completed, the steam crane was moved forward to start the next pier, its place being taken by a steam winch and crane, by which the concrete hearting was put into the cylinders. Concrete of 6 parts broken whinstone, 1½-in. gauge, 3 parts coarse sand, and 1 part Portland cement, was deposited by means of boxes, having doors in the bottom opening automatically when the box touched the bottom and the winch cable was slackened. The concrete was mixed in a "Ransome" drum mixer, driven by a 6 h.p. oil-engine, on the south bank of the river, loaded into the boxes and run on trucks along a service railway to the cylinder. Each box was picked up by the winch, and slowly lowered into the cylinder until the top of the box was an inch or two above the water, where it was held until all the air had bubbled out of the box, which was then slowly lowered into the cylinder. Upon touching the bottom, the box was gently lifted until the concrete was deposited, then hauled out, and returned to the mixer. About 25 to 30 ft. of 6-ft. diameter cylinder was concreted in a day.

The concrete was brought up to the level of the bottom of the reinforcing metals; these were placed and concreted in, and the 4-ft. diameter cylinders, having been prepared in readiness, were dropped over them and set to the exact position and level, and the concrete brought up to the top of the metals. The bracing was all riveted together in one piece previously to being required and, one side of the pier being erected, the bracing was lifted on to blocks at the right level, and fixed to the cylinder with drifts and bolts. The other side of the pier was then brought up to the bracing, and the whole riveted up. The 4-ft. diameter cylinders were then concreted up to the top, and the girder bed plates set to their proper levels on the concrete.

Test Loads on Cylinders.—Test loads were applied to two of the cylinders after they had been filled with concrete, and before the

upper part of the pier was erected. The manner of carrying out the test at pier No. 10 is shown in Fig. 7. Concrete hearting was deposited up to the level of the bottom of the reinforcing metals, and upon the concrete was constructed a timber staging to the top of the cylinder, and standing up 1 in. to allow for compression. At the first cylinder joint above water level, there was bolted on a length prepared with brackets and girders similar to that described for the sinking. The loading applied consisted of 166 tons of railway rails, and on the top of the rails was placed a cylinder filled with sand, the total being 175 tons. The cylinder, concrete, &c., weighed 139 tons, making up a total load of 314 tons carried by the cylinder, and being equal to the maximum load which can be brought to bear on the cylinder. Loading was commenced over the centre of the cylinder, and gradually extended until the width shown in the illustration was reached. Between each row in height of rails there was placed 9-in. by 3-in. timbers to facilitate removal and fastening of sling chains. The loading was done by a steam winch and crane, and was commenced at 12.30 p.m. on May 19, 1905. The following table shows the progress of loading and results at the various stages :—

Date.	Time.	Load.	Total Sinkage.	Remarks.
1905.		Tons.	Inches.	
May 19	12.30 p.m.	Nil.	Nil.	Loading commenced.
,, ,, ...	5 p.m.	55	Nil.	Work suspended for the night.
,, 20	7 a.m.	55	$\frac{1}{8}$	
,, ,, ...	1 p.m.	79	$\frac{1}{4}$	Saturday. Work suspended.
,, 21	9 a.m.	79	$\frac{3}{8}$	Sunday. No work done.
,, 22	7 a.m.	79	$\frac{1}{2}$	Monday. Work resumed.
,, ,, ...	9.30 a.m.	91	$\frac{5}{8}$	
,, ,, ...	11 a.m.	111	$\frac{3}{4}$	
,, ,, ...	12 noon	127	$1\frac{1}{8}$	
,, ,, ...	1 p.m.	146	2	
,, ,, ...	2.45 p.m.	158	$2\frac{1}{8}$	
,, ,, ...	4.45 p.m.	175	$2\frac{3}{4}$	Loading completed.
,, 23	7 a.m.	175	$3\frac{1}{8}$	
,, ,, ...	2 p.m.	175	$3\frac{1}{4}$	
,, 24	7 a.m.	175	$3\frac{3}{8}$	
,, ,, ...	12 noon.	175	$3\frac{1}{2}$	
July 15	—	Nil.	$3\frac{1}{2}$	Check level. Loading removed.

The load was still on the cylinder when the flood of June 1st, 1905, occurred, and the load stood until July 15th, when check levels showed that no further sinkage had taken place, and the cylinder was considered to be stable. Neglecting surface friction, the load of 314 tons would exert a base pressure of 11 tons per sq. ft. Allowing for surface friction at 150 lb. per sq. ft., there would be a total resistance by surface friction of 91 tons, leaving the base load as 8 tons per sq. ft.

Pier No. 12 on the Zululand side was tested in a similar manner. The depth of the cylinder was 73 ft. 8 in. and the load applied was 150 tons. The weight of the cylinder and concrete was 122 tons, making the total load carried 272 tons. During the placing of the load there was only a very minute settlement. Loading was completed at 12 noon on March 10th, 1905, and at 5 p.m. the sinkage was $\frac{3}{4}$ in. At 7 a.m. on the following morning a further $\frac{1}{16}$ in. sinkage had taken place, making $\frac{13}{16}$ in. The load remained on for 3 days and no further settlement took place. Neglecting surface friction the base load was $9\frac{1}{2}$ tons per sq. ft. Allowing for surface frictional resistance at 150 lb. per sq. ft., and neglecting the first 15 ft. in depth, the total load supported by friction works out at 74 tons, leaving the load on the base at 235 tons, or 7 tons per sq. ft.

Superstructure.—A cross section of the superstructure is shown in Fig. 9. The net length of main girders is 77 ft. $2\frac{1}{2}$ in., an expansion space of $1\frac{1}{2}$ in. being provided over each pier. The bed-plates are fixed on the concrete hearting by lewis bolts set in the concrete. One end of each span is bolted down to the bed-plates, the other end being free. The main girders were sent out in three lengths. An erecting stage on piles was constructed on the side of each span, and the main girders erected thereon by means of a steam travelling crane erected on the down stream side and standing at the centre of the span. The crane jib was 60 ft. long, and could reach all over the span. No difficulties presented themselves in this portion of the work. A

complete span weighs 70 tons, and about 12 days were taken to erect and bolt up a span ready for riveting. All the riveting was done by pneumatic power under a pressure of 100 lb. per sq. in., and 5 hammers occupied about 14 days per span.

Upon the completion of the corrugated decking the whole floor was tarred. The troughs were then filled with broken stone and run in with hot liquid asphalt composed of coal tar pitch, anthracene oil, and sand. After the troughs were fil'ed up, a coating of blue whinstone, 5 in. thick at the centre and cambered to 3 in. thick at the curb-plates, was laid down and also run with asphalt, and then steam-rolled with a 12-ton roller. Upon the asphalted stone was laid the macadamised roadway of blue whinstone, 4 in. thick at the centre and 3 in. thick at the sides, and steam-rolled, blinded, watered, and again rolled and finished to a smooth surface, blue whinstone chippings being sprinkled on after the final rolling. The surface water drainage is carried off by outlets and piping from the curb plates; and the asphalted stone prevents percolation of water to the steelwork below.

The bridge footways are carried on brackets riveted to the main girders, and are composed of 9-in. by 3-in. creosoted deal planks carried on and spiked down to 6-in. by 4-in. pitch pine cross bearers bolted to the top flanges of brackets. In addition to the tube fencing, the outsides of each footway are protected by Cyclone wire fencing.

The embankments for approach roads are 40 feet wide, and are made of strippings from an adjoining quarry. The approach roads are 35 ft. between the fences, and are macadamised. The embankment on the Zululand side extends round the front of the cylinder abutment, and is protected by dry masonry pitching, 15 in. thick.

Flood.—On the night of May 31st, 1905, there was an extraordinary storm; the rainfall in Durban was 10½ in. in 15 hours, and at Pinetown, situate on the Palmeit spruit, which is a tributary of the Umgeni River, in the same period 15 in. fell. The Umgeni River rose 14 ft. 1 in., being at its height at 9 a.m. on June 1st, and washed away the old low-level timber bridge. The new bridge was then erected as far as pier No. 5, and no part of the structure suffered any damage. Span 5 was erected on staging and bolted up ready for riveting; the erection stage was completely washed away, and the girders settled down until there was no camber. The span was, however, easily jacked up again to correct level. All the contractors' staging and machinery at pier No. 6 was washed away and deposited on an adjacent island, all mixed up with old bridge timbers and *débris* of all descriptions. A large quantity of timber was carried down to the Indian Ocean. Some of the cylinders lying on an island were rolled away down the river, and much other material was buried in the sand and *débris*. Pier No. 6 was at that time in course of sinking, and a part of the old bridge was washed up against it, and knocked the upper 18 ft. right off by ripping the bolts out of the connecting angles. The flood caused a delay of 2 months in the execution of the works.

As soon as the flood subsided the P.W.D. commenced the erection of a temporary bridge to carry traffic until the completion of the Connaught Bridge. The district engineer, Mr. Arthur Head, assisted by the author, took charge of the work, and within 10 days a bridge some 500 ft. long was available for traffic. As the temporary structure was not required for more than 6 months, it was of a somewhat rough and ready nature. On the sites of the trestles of the old bridge rough piers of stone were built to carry cross sleepers of Oregon pine 12 in. by 12 in., and the spans were bridged with 35-ft. baulks of Oregon pine 12 in. by 12 in., seven baulks to a span. The baulks were decked over with 9-in. by 3-in. deals, and a macadam roadway 19 ft. wide was made, with fences on each side. Where spans were too long for 35-feet timbers, new piers were put in, constructed of railway rail piles and 9-in. by 3-in deal casing, inside which was packed the stone to carry the sleepers. In all, seventeen new spans were constructed, and the damaged spans at each end repaired and joined into the new work.

In conclusion, the author desires to express his thanks to the Chief Engineer, P.W.D., Mr. J. F. E. Barnes, G.M.G., M.Inst.C.E., for his permission to prepare this paper, and especially to Mr. Arthur Head, District Engineer, Durban, for much valuable advice and assistance in the carrying out of the author's duties on the works.

Progress of Engineering in the State of Victoria.

By THOMAS WALKER FOWLER, M.Inst.C.E., M.Am.Soc.C.E., &c.

BEFORE attempting to review the progress of engineering in the State of Victoria, readers may be reminded of its comparatively short history as a European settlement. The eastern and still thinly settled coast was first sighted by Captain Cook on 19th April, 1770, near Cape Everard. He followed it from thence easterly to Cape Howe before tracing the eastern coast of Australia. The next exploration was in 1798, by Dr. Bass, who explored the coast from Cook's most western point, *viâ* Wilson's Promontory to Western Port, whilst the further details were filled in by Lieutenants Grant and Murray in the *Lady Nelson* and Captain Flinders in the *Investigator* between 1800 and 1802. The attempt at settlement by Collins in 1803–4, and the examinations of the interior by Hume and Howell in 1824, by Captain Sturt in 1830, and by Major Mitchell in 1836, should be mentioned. The first permanent settlements were those of the Henty's at Portland in 1834, and of John Bateman at Melbourne in 1835, the latter being followed in the same year by John Pascoe Fawkner. The pastoral industry was the first to develop, and at the first census (1838) the population was 3,511, increasing to 11,738 in 1841, 32,879 in 1845, and 77,345 in March, 1851. In July and August of that year gold was discovered, causing the population to increase by leaps and bounds, being 236,798 in 1854, and 410,766 in 1857, reaching 1,140,405 in 1891, 1,201,341 in 1901, and estimated at 1,218,842 at end of 1905. The area of the State is estimated at 87,884 square miles, or say 56,250,000 acres, of which 26,346,802 acres were at the end of 1905 either alienated or in process of alienation and 15,067,561 acres were areas of roads, reserves, &c., or held under grazing licenses, &c. It is intended to briefly note the various classes of engineering works as follows: maritime works, railways, roads, water supply and irrigation works and sewerage works.

Dealing first with maritime works, the Victorian coast line is lighted with first order sea lights at Capes Nelson and Otway, Split Point, Cape Schanck, Wilson's Promontory, Cape Everard and Gabo Island, whilst a third order revolving light has been erected on Cliffy Island. Harbour lights of importance have been erected at Portland, Port Fairy and Warrnambool, whilst the entrance to Port Phillip is marked by the Point Lonsdale and Queenscliff high and low lights, the interior channels being defined by three pile lights, and one on an elevated iron tower near Arthur's Seat, Dromana. The sea lights are carried on massive stone or concrete towers, the locally available material being used throughout. Owing to the comparatively fine climate, and hence the small liability of fogs obscuring the lights, a number of them have been placed on fairly high cliffs, as at Capes Otway and Schanck and Wilson's Promontory, each of which are over 300 ft. above sea level, although the towers are each only about 60 ft. high. The light on Deal Island (Kent's group) at the eastern end of Bass Strait is one of the highest in the world, being 950 ft. above sea level, but from its great elevation is sometimes obscured by low clouds and fogs. It is under the jurisdiction of Tasmania. The Gabo Island light, 179 ft. above sea level, is carried in a tower built of the local red syenite,

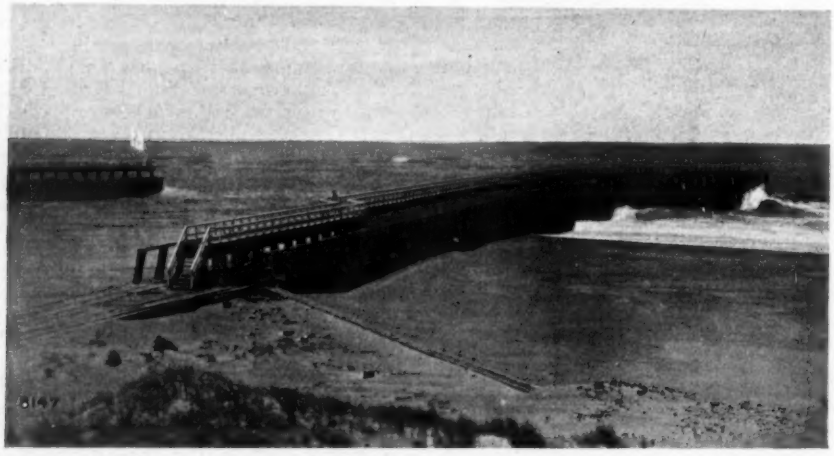
the foundation being about 30 ft. above sea level.

Revolving lights are used at Capes Otway, Schanck and Everard, and at Cliffy Island, the others being fixed. The "Catoptric" system is still in use at Wilson's Promontory, the "Dioptric" system being used elsewhere combined with Stevenson's holophotal reflectors in the cases of Cape Nelson, Split Point, Point Lonsdale (occulting) Queenscliff low light and Dromana light. In the two latter instances vertical prisms are also used to concentrate in the directions mostly required the otherwise unused light.

In the majority of the lights the illumination is by multiple wick lamps of the "Fresnel" type, as subsequently modified by Douglas, mineral oil being used. In three instances, however, incandescent mantles are adopted, and these have proved so satisfactory that their use is certain to extend.

For lighting beacons and buoys in Port Phillip, extensive use is made of "Pintsch" gas, the reservoirs being filled once in six weeks. On out stations "Wigham" automatic trimming oil lamps are coming into use with satisfactory results.

The lighting of the Victorian coasts, so far as it goes, may be considered fairly satisfactory, but a greater number are required; especially one is needed on one of the Glennie Islands near Wilson's Promontory to light the approach from the westward. At present vessels pass the principal dangers on that side before sighting the light. It will in addition be probably found necessary ultimately to substitute powerful and rapidly revolving lights for the fixed sea lights now in use and for the slowly revolving light at Cape Schanck.



ENTRANCE TO GIPPSLAND LAKES.

It may be noted that Victoria possesses no rock lighthouses, and that the three pile lights are wooden structures. In South Australia a number of iron lighthouses have been constructed in the open seas, and the Engineer-in-chief states that they have given absolutely no trouble from corrosion although some have been up for many years, in one instance nearly forty.

The principal Victorian harbour is at Melbourne, but in addition those of Portland, Port Fairy, Warrnambool and Geelong are utilised in addition to those of the Gippsland Lakes. Portland Bay is fairly well sheltered during south-east

gales, and ocean steamers, in fine weather, go alongside a fine timber jetty 2,400 ft. long, with 31 ft. of water at the end berths, the local trade being provided for at a smaller jetty close by. For the protection of the local fishing craft a rubble breakwater, capped with concrete in mass, was constructed, and has been fairly effective, although a certain amount of silt has accumulated behind same which will require removal by a sand-pump dredge. The rubble mound has settled since the mass concrete was put in place, and hence the latter has cracked in places, although not so as to endanger the stability of the work.

The Port Fairy harbour is situated on the Moyne river, which has been trained and improved so that vessels drawing 10 ft. can enter.

Warrnambool is the business centre of an important agricultural and pastoral area. Originally provision was made for its commerce by two small timber jetties at the western end of Lady Bay. These were very exposed, and acting on the advice of Sir John Coode a concrete block breakwater was built, projecting in an E. N. E. direction from Breakwater Rock, one of a series of small islets off the west end of the bay and opposite the mouth of the Merri Creek. The foundation is sandstone rock, and the blocks vary in volume from 10 cub. yds. to 14½ cub. yds. The blocks are laid horizontally in courses, those above water level being laid in cement, those below without. The upper surface is finished off to serve as a pier, a projecting parapet being provided on the sea side, and the breakwater is connected with the shore by a timber viaduct, which permits of the littoral current sweeping through the harbour. Silting has taken place, however, and a sand pumping dredge has to be used occasionally.

The entrance to Port Phillip is 1⅜ miles wide, but reefs projecting from either side reduce the navigable channels to half a mile. As Port Phillip Bay is very extensive (its area being over 500 square miles) and the tidal range outside is about 7 ft., a very strong tidal current passes in and out between the heads. This has increased the difficulty of removing dangerous submerged rocks or pinnacles. These are the Tertiary

GOULBURN WEIR, VICTORIA.

sandstones, and many years ago were removed sufficiently to give a clear depth of 30 ft. at low water. In view of the increased size of vessels using the port further deepening is being done, the object being to secure a clear depth of 40 ft. at low water. The rocks are shattered by charges of dynamite put in place by divers at slack water, ordinary dredging operations being impossible owing to the currents, &c.

CREST OF LOWER STONY CREEK RESERVOIR, GEELONG.

Whilst the greater portion of Port Phillip Bay is of ample depth, going up to 12 and 13 fathoms, a series of sand banks, intersected by channels, exist at the southern end. The western one forms the more direct approach to Melbourne and Geelong and is available for vessels drawing 17½ ft. It has been buoyed, no other improvements being required. The south channel is the one used by large vessels, and has for the greater length ample depth, but dredging has been resorted to near the eastern end to allow of the larger vessels passing at all stages of the tide.

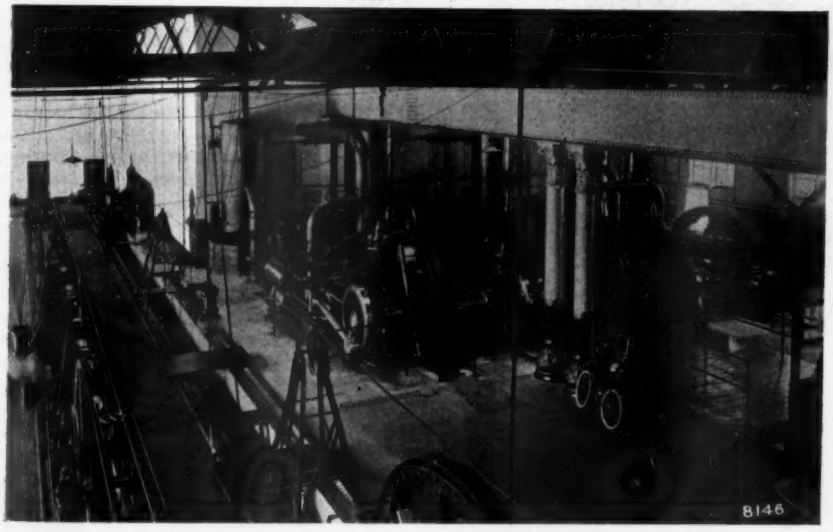
Geelong harbour is in the south-west corner of Port Phillip, several timber jetties being provided. A shoal lies across the entrance, and the Hopetoun Channel has been dredged through the same, the present depth being 22 ft. at low water, and this is being increased.

Melbourne is situated on the River Yarra, which originally was a comparatively narrow and tortuous stream, up which vessels of small size only could be navigated, and the larger ships anchored in Hobson's Bay or were berthed at the piers projecting into that bay from Williamstown or Sandridge, the latter being now called Port Melbourne. In 1879 Sir John Coode reported on various proposals for improving the port, and recommended the straightening and deepening of the river, the result being that it is now regularly navigated by interstate steamers of 7,000 tons register, the depth in the river being 26 ft. at low water. To effect this 21,652,371 cub. yds. of material have been dredged from the river. The latter being deepened beyond its self-scouring capacity, the dredges have to be kept going regularly to maintain the depth.

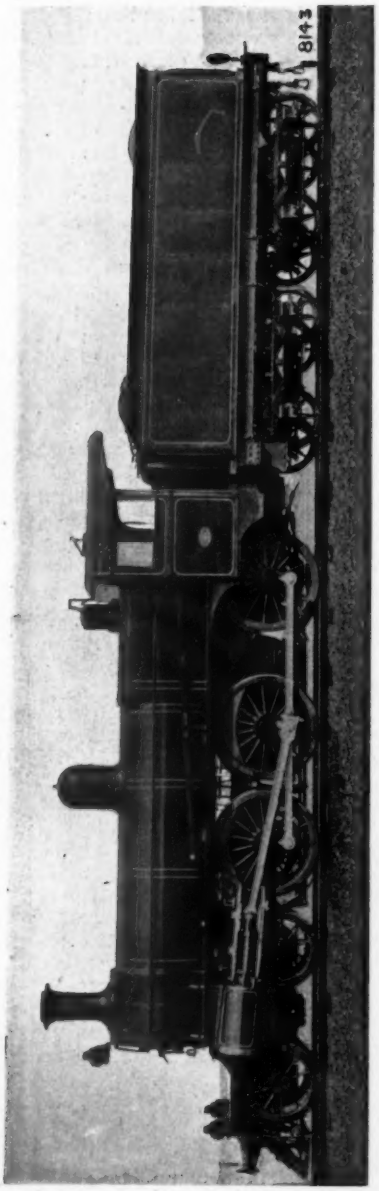
The Gippsland lakes have an area of about 200 sq. miles, and are separated from the ocean by a low line of sand

hummocks. They are fed by the Latrobe, Thomson, Macallister, Mitchell, Tambo and other rivers, and the littoral drift being to the north-east the entrance was forced to that end of the lakes. Originally it frequently moved and usually had a depth of from two to three feet, but in 1883 works (which were completed in 1888) were commenced for fixing the entrance. These consist of two jetties 475 ft. apart at the lake end and 275 ft. apart at the sea end, the eastern pier being 475 ft. and the western one 650 ft. in length. The foundations throughout are sea sand of unknown depth. The adopted design for each pier consisted of three rows 30 ft. apart of main piles 20 in. dia. at head and 10 ft. centres, connected by rows of cross piles every 30 ft., all being securely held in place by heavy walings. Five intermediate piles, 18 in. dia. at the head, were then driven between each pair of main piles and each compartment was filled with rubble stone, of which two-thirds were over 1½ cub. ft. volume each. In fixing and deepening the entrance the work has been most successful. The first flood cleared out the intermediate sand, after which the lakes became tidal and a heavy scouring action set in. At the lake end a depth of 24 ft. has been obtained, whilst between the piers it varies from 70 ft. to 80 ft. About 600 yards to seaward a sand bar has formed, the depth over which varies from 13 ft. to 15 ft.

The stone in the compartments speedily sank into the sand, and has been replaced from time to time with fresh material filled in from the top. Settlement of the stone has now apparently ceased, and it appears as though the pile compartments have acted as funnels, through which the stone has been fed into the sand bed without lateral spreading, such as would have been inevitable had a rubble mound foundation been formed in the ordinary way. The works would probably have lasted as constructed for many years, but for the ravages of the *Teredo-navilis*, which attacked the piles used. These were of Gippsland red iron bark (*Eucalyptus Leucoxylon*), one of the strongest and most durable of Australian hardwoods,



MELBOURNE TRAMWAY ENGINE HOUSE.



VICTORIAN RAILWAYS: SIX-COUPLED GENERAL ENGINE.

but evidently unsuitable for use in sea waters infested with the *teredo*. The piers are now being reconstructed in concrete block resting upon the rubble stone previously deposited, and this will bring the total cost of the works up to about £140,000. Had reinforced concrete piles been available at the time the work was originally constructed they could have been used with advantage instead of the timber piling, and no doubt would have formed a durable structure.

After careful study of these works the writer has formed the opinion that they would have been even more successful had the training walls been placed farther apart and had the whole works been located some distance to the south-west so as to permit more direct tidal access to the lakes. In this way the maximum possible tidal scour would have been obtained and the bar would have formed farther to sea and at a lower level.

Railways.—The first railway constructed in Victoria was that from Melbourne to Sandridge (now Port Melbourne) which was opened on September 13th, 1854, the gauge being 5 ft. 3 in. The early lines generally were laid with double head rails, but for many years all new work and all renewals have been with those of the "Vignole" type. Three standard sections are now adopted, 100 lbs. for all suburban lines, 80 lbs. for main country lines and 60 lbs. for the branch lines. The lengths are 33 ft. with twelve sleepers per rail length. The joints are suspended and in new work staggered, six-bolt fish plates 2 ft. 6 in. are used, those on the inside of angle section and on the outer of channel section both extending over the joint sleepers. The fishing angles are, upper 1 in 3 and lower 1 in 5. No tie plates are used, it being found that the rails do not cut into the local hardwood sleepers. On sharp curves guard rails are provided and rail braces are used on such curves, being usually fixed to the guard rail and not to the outer rail.

In the earlier railways 1 in 50 was

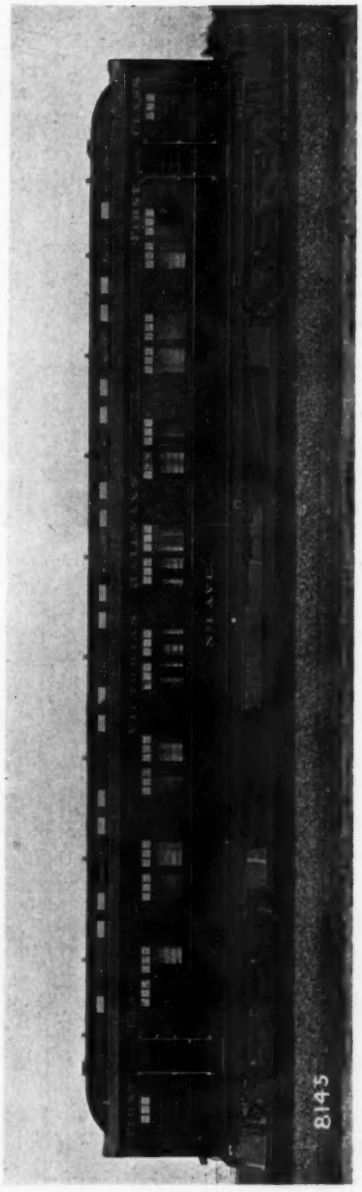
adopted as the ruling gradient, and 40 chains for the sharpest curves. The heavy grades are rendered necessary by the character of the country, the main Dividing Range traversing the State from east to west and passing about thirty-five miles north of Melbourne. The saddles through which it is crossed by the Northern and North-Eastern lines are respectively 1,850 ft. and 1,145 ft. above sea level. In more recent work the tendency has been in the direction of easier grades and sharper curves although in some cases steeper grades have been found necessary as, for instance, 1 in 30 on the Beechworth line.

In the country level crossings are extensively adopted, and originally gates and gate-keepers were provided at each, but in more recent years cattle pits with grids have been extensively adopted. All lines are fenced with the exception of a portion of that to Mildura.

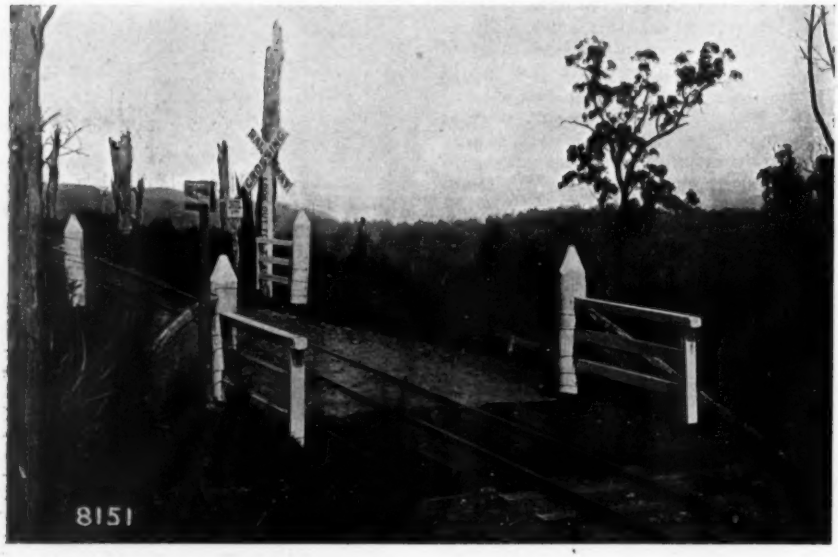
The most important viaducts on the Victorian Railways are Moorabool, Werribee, Taradale and Malmsbury, whilst there are tunnels at Elphinstone, Harcourt, Geelong, Heidelberg, East Melbourne and Yarrawarra.

About ten years ago narrow gauge construction was introduced in connection with a few railways in mountainous country, a 2 ft. 6 in. gauge being adopted with three chain curves and 1 in 40 grades. Whilst the cost of construction has been reduced the inconvenience from break of gauge is considerable and the speed is necessarily kept very low. Already one serious accident has happened on one of these lines, but fortunately no lives were lost.

The following particulars of some of the engines used may prove of interest. Express engine, four coupled drivers 6 ft. 1 in. diameter and four-wheel bogie, maximum weight per axle 16 tons 10 cwt.; heating surface 1,440 ft.; inside cylinders 19 in. × 26 in. Total weight (road worthy) 88 tons 1 cwt. Tractive power 20,860 lbs. New type of general engine six coupled drivers 5 ft. 1¾ in. diameter and four-wheel bogie, maximum weight per axle,



NEW CARRIAGE AS USED ON THE SYDNEY EXPRESS, VICTORIAN RAILWAYS.



ROAD CROSSING SHOWING CATTLE-PITS; GEMBROOK RAILWAY, VICTORIA.

12 tons; heating surface 1,408 ft.; outside cylinders 18 in. × 26 in. Total weight (road worthy) 89 tons 18 cwt. Tractive power 20,000 lbs. A very heavy goods engine has been tried having coupled drivers 4 ft. 6 in. diameter and two-wheel bogie, maximum weight per axle 12 tons 6 cwt.; heating surface 1,486 ft.; outside cylinders (compound) 13 in. and 22 in. × 26 in. on each side. Total weight (road worthy) 87 tons 5 cwt. Tractive power 26,430 lbs. The type is not, however, generally considered successful and frequently visits the repairing sheds. A new class of engine with greater tractive force is contemplated. The general arrangement is as follows:—Six coupled drivers 6 ft. diameter and four-wheel bogie; maximum weight per axle 16 tons 10 cwt.; heating surface, 2,200 ft.; outside cylinders 21 in. × 26 in. Total weight (road worthy) 108 tons. Tractive force, 25,480 lbs.

The passenger rolling stock originally was of the four-wheel and six-wheel old British type, but bogie stock is now generally in use, cross seating and a side corridor being adopted. The usual type is 53 ft. 6 in. over buffers, carried on four-wheel bogies and weighing 24 tons 16 cwt., but on the Sydney and Adelaide express trains six-wheel bogies are used with carriages 74 ft. long over the buffers and weighing between 34 tons and 35 tons.

All new engines and carriages, &c., are now manufactured at the Departmental Workshops, Newport, from the designs and under the supervision of Mr. T. H. Woodroffe, M.Inst.C.E., Chief Mechanical Engineer of the Victorian Railways.

The railways are all State owned and the total mileage at end of 1905 was as follows:—Broad gauge, 312 miles double line, 2,966½ miles single line. Narrow gauge, 81½ miles single line. The total cost of construction was £32,231,083, or an average of £9,365 per mile whilst the equipment, rolling stock, &c., brought the total up to £41,259,378.

Roads.—Victoria can show various specimens of road and street construction. In the hilly and heavily timbered districts where trees about 250 to 300 ft. in height and from 30 to 60 ft. in circumference are met with, the pioneer settlers are glad to get tracks of any kind, and hence, in such cases "corduroy roads" are freely used. These consist of round saplings or split timber (the latter being more durable) laid in contact transversely to the line of traffic on a levelled bed of earth. In the northern districts where stone and gravel are scarce earthen roads have to be adopted, the crown being well rounded up in wet country. Again, in other localities where stone is plentiful good macadamised roads are to be found, and the streets are generally made with either plain or tarred macadam. In Melbourne extensive use is made of wood paving laid on a 9-in. bed of cement concrete, red gum and iron bark blocks being generally adopted. Under fairly heavy traffic a life of eighteen years has been obtained, after which the blocks have been lifted, retrimmed and laid again in localities where the traffic is lighter. To the city surveyor, Mr. A. C. Mountain, M.Inst.C.E., is due the credit of perfecting the Melbourne system of wood paving.

Tramways. — The Melbourne tramways are noted as being probably the most extensive cable system in existence, there being 47½ miles of double track in addition to 3¾ miles of horse tramways, the cost being £1,700,000. Some of the lines have been open for twenty-one years, the last being completed in 1891, and except on curves no renewals have so far been required. Through careful study of the local conditions the amount of work got out of the cables has been greatly increased, some being used for over twelve months before requiring renewals.

Electric tramways have been installed at Bendigo and Ballarat, whilst the Government has constructed one from

BRIDGE ON CURVE, GEMBROOK NARROW-GAUGE RAILWAY, VICTORIA.

BACTERIAL FILTER BEDS AT ELMON, VICTORIA.

St. Kilda to Brighton, and a private company another from North Melbourne to Essendon.

Water. — The Melbourne water supply is controlled by the Melbourne and Metropolitan Board of Works and two sources of supply are provided, a high level service from Yan Yean and a low level one from the Watts River at Maroondah. The Yan Yean reservoir is situated on a side valley of the Plenty River and is filled through a tunnel. Originally the supply was obtained entirely from south of the Dividing Range, but in view of the advance of settlement a considerable area has been excised from the catchment, the loss being more than made up by additions of the catchment of the upper parts of the Wallaby and Silver Creeks, which naturally drain northerly to the Goulbourn. The waters of these streams have been divided by weirs and contoured races to a low saddle in the range, whence they are carried to the Yan Yean reservoir. All settlement is strictly prohibited on the catchment areas of the Melbourne water supply which are kept covered with virgin forest. The majority of the aqueducts are open, but where they pass through settled districts all local drainage is carefully excluded from them. The analyses prove that the water is remarkably pure, both from chemical and biological standpoints, and no filtration is adopted.

The supply to the northern goldfields towns is from the Coliban Waterworks, the principal works being two large reservoirs with earthen embankments, one at Malmesbury and the other near Kyneton, from whence the water is conveyed in open channels to service reservoirs near the points to be supplied. Ballarat has a satisfactory supply from Gong Gong, and Geelong draws its

supply from the Moorabool, near Ballan, and the Stony Creek reservoirs. The lower reservoir is a handsome gravity dam, curved in plan and remarkable for its small crest width of 2 ft. 6 in. It has been erected for over thirty years and has proved perfectly satisfactory. Space will not permit of further reference to to town water supplies.

Extensive works have been and are being carried out for water supply to country districts, including irrigation. Amongst these may be mentioned Casey's Weir on the Broken River, carried out by the writer over twenty years ago, which provides a stock and domestic supply for an area of nearly 1,000 sq. miles. The most important system of works, however, is that in connection with the Goulbourn weir which raises the summer level of the river 45 ft. The western offtake channel from the weir has 110 ft. normal bed width and 1½ to 1 slide slopes with 7 ft. carrying depth, the grade being 6 in. per mile. This is 24 miles long, and discharges into the Waranga Basin which forms a storage, the capacity being 54,000,000,000 gallons. The area at full supply level is over 18 sq. miles, the storage being formed by constructing an earthen embankment 4½ miles long and about 30 ft. high across the outlet of the old Waranga Swamp. From this basin it is intended to carry a main channel westerly towards the Mallee, a portion having been already constructed.

Sanitary. — Dealing next with sanitary matters it may be mentioned that Melbourne has now an excellent sewerage system which has already been carried to the majority of the suburbs. The separate system has been adopted and the sewers all lead to the Spottiswood pumping station, whence the sewerage is pumped to the Werribee sewage farm, the area of which is 8,847 acres. Some of the other towns are contemplating the adoption of a sewerage system, but at the present time, outside the Metropolis the pan system is almost universal. In cases of a few private houses and public institutions, &c., installation worked on the septic system have been adopted. At Elmore some two years ago, the writer installed a septic tank and bacterial filters, as shown in the illustration, to deal with the town drainage, which was necessarily discharged into the river Campaspe and hence had to be rendered as pure as possible, the river being used for drinking purposes lower down.

Manufactures. — For a new country Victoria has developed local manufactures to a very considerable extent. The various engineering shops turn out engines and machinery well suited to local requirements, and in addition supply many of the Australian States, more especially with mining machinery. The manufacture of cement is a flourishing and important industry, and the use of that material in connection with reinforced concrete is rapidly extending.

To one of Victoria's most prominent mechanical engineers, Mr. Mephan Ferguson, is due the credit of introducing the locking bar pipe which has been used with great success on the Coolgardie waterworks and elsewhere, securing a very considerable economy in construction.

Conclusion.—Victoria has expended over £41,000,000 on its railway system, about £10,000,000 on water supply and irrigation works, £5,000,000 on sewerage works and many millions on the construction of roads and streets, tramways and harbours, the expenditure on the Melbourne Harbour Works alone since 1877 being £2,500,000. When it is remembered that the first permanent settlement in Victoria (that at Portland) was commenced on 19th November, 1834, it is evident that Victorians have shown an enterprise worthy of the Anglo Saxon race from which they have sprung.

RAILWAY ENGINEERING NOTES.

Mr. T. Hurry Riches on Modern Railway Practice.*

It is probably expected that I, as a railway man, should have something to say upon that side of mechanical engineering, and more particularly with reference to the rolling stock and machinery used. I will touch only lightly upon past history. On previous occasions, when the late Mr. Joseph Tomlinson and Mr. Samuel W. Johnson were respectively presidents, they then gave you railway practice to date, and it would, therefore, be going over ground unnecessarily if I attempted to deal in detail with what might now be termed, more or less, ancient history. I, therefore, only call attention in passing to the considerable strides that have been made in the size of locomotive engines and vehicles. As all of you know, the original rolling stock of the Liverpool and Manchester and the Stockport and Darlington Railways, if existent to-day, would be looked upon as toys compared with our modern engines and vehicles.

To put it briefly, the dimensions of both locomotives and rolling stock have grown out of all comparison with those of the past, and the speed of trains has been enormously increased. The relative size and capacity of ancient and modern locomotives is well shown by the diagrams of the "Rocket" and one of the latest express locomotives, also two recent goods locomotives (Figs. 1—4). The respective tractive effort of each, and the relative heating surface are given, and in plates illustrating the locomotives and rolling stock of the railways of Great Britain (which have been reproduced from photographs, &c., kindly supplied me by my friends, the locomotive, carriage, and wagon superintendents), I am enabled to show to-day's practice in this country. It will be observed from these illustrations that modern requirements are gradually bringing the locomotives on the railways generally more and more into accord with one another, where the work to be done is similar.

It must be noticed that, within the last few years alone, the speed of trains has materially increased, the necessity for more rapid transport of both passenger and goods traffic has become much more urgent, and this tendency towards higher speed will without doubt be still further developed in the future.

The long-distance express traffic, namely, that of trains travelling for over 100 miles without a stop, has also during recent years considerably increased, and it might here be noticed that one result of these long runs, such as between Plymouth and London, Carlisle and London, York and London, Carlisle and Edinburgh, &c., has been to develop the necessity of using the late Mr. John Ramsbottom's water-trough method. He, I believe, first introduced that appliance, and was for a long time the only locomotive superintendent to use that system of picking up water. That practice has now been copied, and Mr. Ramsbottom's arrangement has been in some measure improved upon by the engineers of several of the great railways.

The requirements of the public and competition combined have rendered it imperative that coaches of much larger dimensions and of more luxuriant fitting and comfort should be provided, at least upon the leading railways; but these great carriages, some of 35 tons weight and upwards, have enormously added to the weight per passenger to be hauled. These extra demands have made it absolutely necessary that the locomotives should be more powerful. This desideratum, however, owing to the limited load and structure gauge on British railways, has been difficult to accomplish. The limit of width and height has so circumscribed the area within which everything must be placed, that the British engineer has much more difficulty in producing the great locomotive and carriage of to-day than has his foreign or American

* Extract from the Presidential Address, Institution of Mechanical Engineers.

Locomotive.	Cylinders.	Driving Wheels.	Coupled Wheel Base.	Boiler.		Grate Area.	Weight in Working Order.	Tractive Force on Rails.
				Pressure.	Total Heating Surface.			
	ins.	ft. in.	ft. in.	lbs.	sq. ft.	sq. ft.	tons cwt.	lbs.
Rocket	8 by 16½	4 8½	—	50	137	6	4 5	750
Great Northern Railway passenger	19 „ 24	6 8	6 10	175	2,500	31	65 10	15,160
Great Northern Railway tank	20 „ 26	4 8	17 8	175	1,044	17·8	70 5	26,000
Lancashire and Yorkshire Railway tank	19 „ 26	5 8	12 4	180	2,039	26·05	77 10	19,875

contemporary. For this reason one sometimes regrets that the 4 ft. 8½ in. gauge was the one that ultimately triumphed in the battle of gauges, but whilst saying this it must be realised that the old broad gauge was not an ideal one, and we are led to wish that the 5 ft. 6 in. gauge had been that adopted. It would have given room, not only for cylinders and motion work, but would also have enabled journals to be lengthened without crippling other dimensions.

A word of regret I must express, that the fine old single-driving-wheeled locomotive has to be superseded. The excellent engines of this type on the Great Western, Great Northern, London and North-Western, Midland, and other railways in the country, did admirable work so long as the trains they were required to haul did not exceed their tractive capacity; but the day seems to have arrived when sufficient adhesion cannot be obtained on one pair of wheels to utilise the increased tractive capacity of the modern locomotive, with the result that two or more pairs of wheels have now to be coupled to utilise the power produced. There is one other feature of the modern locomotive, namely, instead of using the large wheels, which were favourites in practice of thirty years ago, a smaller wheel is more frequently used, and greater care taken in balancing to avoid undue oscillation.

As the result of the ever-increasing demands made upon the locomotive, and owing to the limited dimensions within which enlargement may be made, the design of the boiler has been brought very prominently under consideration. With the increased steam-pressure used to-day, it follows that a much larger fire-box and much greater heating surface are imperative. In connection therewith numbers of devices and experiments have been tried with more or less success; I do not, however, propose here to criticise the work of any designer, but to merely mention the fact that these devices have been brought into existence. This part of the subject has been so fully dealt with in Mr. Churchward's paper, that I could not, in the space I have available, attempt to do equal justice to it.

Fig. 1.—Stephenson's "Rocket" (Liverpool and Manchester Ry.).

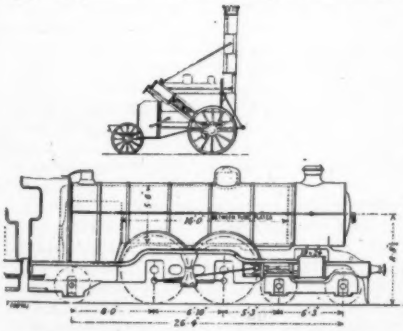


Fig. 2.—G. N. Ry. Express Passenger Engine, 1902.

Fig. 3.—Modern Tank Engines (G. N. Ry.).

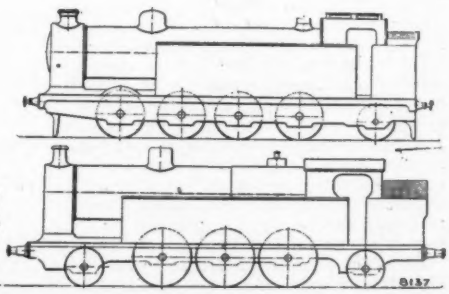


Fig. 4.—L. & Y. Ry.

FIGS. 1—4.—COMPARISON OF OLD AND NEW LOCOMOTIVES

First, there is the cone boiler, with the large fire-box, having a large space round the box and above the crown so as to give plenty of steam space, the barrel gradually tapering down to a smaller dimension at the leading end. This practice has been growing now for many years.

Next, there is the Belpaire fire-box, which has been introduced into the British locomotive now for some years with more or less success, although doubtless this class of boiler requires greater care in construction, and somewhat greater care in management and repairs, to maintain and work it as economically and for as long a time as was the case with the older class of boiler.

Next, the plan of Mr. Drummond, where he uses cross tubes in the fire-box, and where, I understand, he has succeeded in getting a considerably improved evaporative duty in consequence. It must not be forgotten, however, that many years ago some of our predecessors used water mid-feathers and transverse tubes. It is true that these were of large diameter, but whether from the lack of experience or from the lower quality of material that had to be used, all those old schemes have passed away as being too costly to maintain and too difficult with which to keep stock running constantly. In these days of high pressures, not only in the sense of steam pressure, but also of heavy and continuous work by the locomotive, it is essential that the boiler should be well and, as far as possible, simply made, so that its maintenance and treatment may be easy and economical, because the larger firegrates and heating surfaces, together with the more rapid generation of steam at much higher pressure, have put upon the modern locomotive boiler much extra stress compared with the older type.

Whilst upon the question of boilers, what is forced upon the attention is the necessity for a purer supply of water. Many railways have adopted some plan for the softening of the water used in their locomotives; this, no doubt, has assisted to prolong the life of the boiler, and to make some economy in the consumption of fuel; but there is still a good deal to be done in producing a better result, particularly in reducing the cost of purifying the water.

Before leaving the subject of the locomotive, I should like to touch lightly upon the compound type. As is well known, many efforts have been made with more or less success to introduce compounding, but there does seem one requirement that has not been fully accomplished, namely, to get full effect out of the steam. It would appear that this might be improved if some method of condensation could be applied, and I cannot help thinking that with the facilities now existing on many railways for picking up water, it might be possible to apply a condenser, and so assist in front of the piston by obtaining at least a partial vacuum and then pumping the condensed steam back into the boiler at high temperature.

To mention some of the small improvements placed upon locomotives of later years, the cab is now almost universally used. All gauge-glasses are covered and protected from causing injury to the men, and water-gauges are placed upon tenders or other tanks to save the men from risks, which used to exist in their having to leave the foot-plate, when the locomotive was running, to ascertain the condition of their water-supply. Power brakes are now almost universal upon locomotives, and, therefore, the men have much better control of their engines and trains.

I will now refer to the carriage stock. There are some of us, at any rate, who will remember the introduction of the Pullman cars; it took a long time for the British public to accept them, but since those days, and more particularly in recent years, a large number of the railways have built coaches more or less upon the line of the "Pullman," and in some cases have improved upon it.

Carriages.—I have already referred to the question of the amount hauled per passenger carried; that weight has increased from a little over 2·3 cwt., to as much, in some cases, as 30 cwt. per passenger, but not only has the seating accommodation allowed per passenger been increased, but the seating accommodation provided per train has also enormously increased compared with the number of passengers actually carried. There is no doubt that great waste is being constantly incurred in the hauling of vehicles, a large percentage of the seats of which are empty for a considerable portion of the journey. I do not blame the managers in all cases, because the public are continually demanding more room and better accommodation, forgetting, or otherwise ignoring the fact, that to let one passenger have a compartment to himself is most unreasonable, as in many cases only a single passenger is carried, where at least six ought to occupy the compartment. This fact is one of serious import to the dividend-earning of the railways, and if it could be remedied, so that the carriages hauled were better filled in proportion to their seating accommodation, it would be an enormous advantage to the railway companies, and I

cannot help thinking, no serious loss to the public.

Wagons.—Very much of what I have said in reference to passenger stock is equally true in reference to stock for goods traffic. Although a large percentage of the goods wagons of the railway companies are built to carry 8 and 10 tons; the average weight carried by these vehicles rarely exceeds 2 tons, and, therefore, if it were possible to put the load of a train into the wagons capable of carrying the weight, the load to be hauled would be reduced by at least 50 per cent. through the saving in tare weight. This is a matter that in the interests of the country at large should surely have better attention. It is often urged that still larger wagons should be used in England, and that the practice on the British railways should be brought more closely into line with that of the American. It must not be forgotten, however, that a large percentage of the traffic over the latter railways is carried for much longer distances than is the case in this country, and, further, that the load per vehicle is very much higher than is the case here. It is moreover also a fact that quite recently a strong effort has been initiated by those in charge of the American lines to stop what they realise as the enormous waste of vehicles compared with the loads carried, and I understand this matter is now receiving, and will receive, much better attention by them than has been the case in past years.

As to the use of the larger wagon in this country, there are practically few classes of traffic they are at all suitable for; those they may be useful in dealing with may be summed up in five or six items: Coal, iron ore, rails, stone, and some few other heavy commodities of the kind. But it must still be remembered that even with the coal a large amount of the traffic of this country is required in comparatively small lots of 10 tons and below, because the wants of the purchasers do not exceed these quantities, and to send a 30 or 40-ton wagon carrying 10 tons or less is too wasteful. Even for shipment traffic, a large number of ships, particularly in the coasting trade, take small cargoes, and to be unable to divide 50 or 60 tons in smaller lots for completing a cargo would be highly inconvenient, particularly so when coal is sent from the colliery and not consigned to a particular ship. Where the traffic, however, is required in large quantities, and the points of loading and discharging are nearly constant, the large wagons are desirable, and are certainly being used in this country wherever a suitable place can be found for them.

In wagon stock some efforts have been made to introduce into this country automatic couplings, but not so far with much success. Either-side brakes have also been devised with more or less success, and roller bearings are being tried to a limited extent on some wagons. Specifications have been agreed to and passed by the railway companies for wagons of 10, 12, 15, 20, 30, 40, and 56 tons capacity.

There is only one other matter which, perhaps, calls for any remarks from me as to railway traffic, and that is the development of railway steam motor cars. A great deal of controversy has arisen over this type, and having had some experience of it, I say that for sparsely-populated districts, and indeed for close traffic in short distances, I look upon these self-contained cars as eminently successful; but when they are used to take trailer-cars, and are in fact converted into "mixed" trains, then I think their advantages very soon disappear. Under such circumstances the method which is being adopted on the London and South-Western, and London, Brighton and South Coast, and some of the other railways, including the Taff Vale, of fitting carriages that can be attached to an ordinary locomotive, and by which arrangement that locomotive can be driven from the leading end of the carriage when it is being pushed in front, is the better method of dealing with mixed traffic.

Electric Traction.—It would not be right if I were to dismiss the subject of railway traction without at least touching lightly upon the question of electric traction. Here similar questions arise as in the case of steam cars; electricity may be in the same way abused if not used properly. In the case of passenger traffic there can be no doubt that for frequent trains, for not too long distances, and for frequent stops and high speeds, electricity is extremely useful and desirable.

As regards the utility of electric traction on goods and mineral traffic, I cannot help believing that those of our members dealing with this problem will find it worth consideration in the highest degree to solve the question of regenerative control. There are, for instance, in South Wales and many of the mining districts, cases where the loaded wagons come down hill and the empties have to be taken up. If it were possible to use the gravity and momentum of the down train to generate current for the up traffic, and that at a reasonable cost, then it ought to make an enormous difference in the possibilities of electric traction for such purposes. Why should not the slowing and

stopping of trains be done by retardation of the electric motor instead of by brakelocks, and this force returned electrically to the generating station for other use? When I have spoken of this to electrical engineers I have been met by the reply that they can use electric brakes. But where is there a safe one, and where is the saving unless the retardation creates current that can be usefully absorbed elsewhere?

Extensible Gauge Truck.

The question of through tramcar running between Bradford and Leeds has been rendered difficult by the fact that the difference between the gauges of the two systems is 4½ in. A suggestion was made by the Leeds Tramways Committee early last year, at which time it was proposed to lay down a third rail between the two towns to carry out which would have cost approximately £20,000.

As an alternative a suggestion was submitted to the joint committee, of drawings of a car equipped with wheels which could be adjusted to run on either gauge, according to an idea by Mr. C. J. Spencer, A.M.I.E.E., the General Manager of the Bradford City Tramways, in conjunction with Mr. J. W. Dawson, A.M.I.E.E., the Assistant Engineer.

After consideration the Bradford Tramways Committee decided that an experimental car should be fitted with the invention, and if successful, this would obviate the necessity of incurring the expense of obtaining powers for and the laying down of a third rail.

The adjustable axles were made and fitted to a car at the Thornbury Car Works of the Bradford City Tramways, and after a series of severe tests had been made on it by Major Pringle, of the Board of Trade, that official gave his approval for the car to be run in service.

The principle upon which the invention is based is that each car wheel is mounted independently upon a sleeve which revolves on the axle together with its gear wheel. The armature spindle carrying a pinion at each end engages respectively with the gear

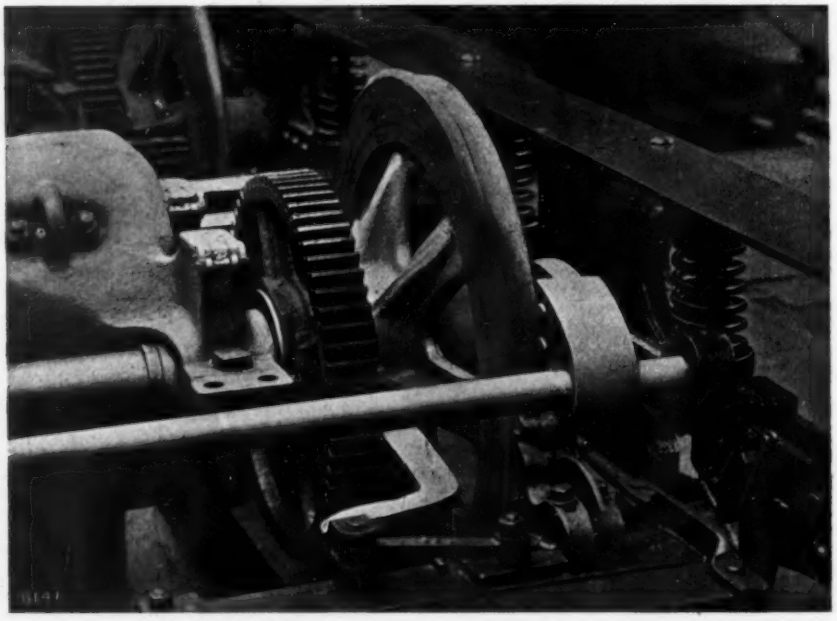


FIG. 5.—THE TRUCK ON 4-FT. GAUGE, SHOWING DISTANCE BLOCKS ON OUTSIDE OF WHEEL

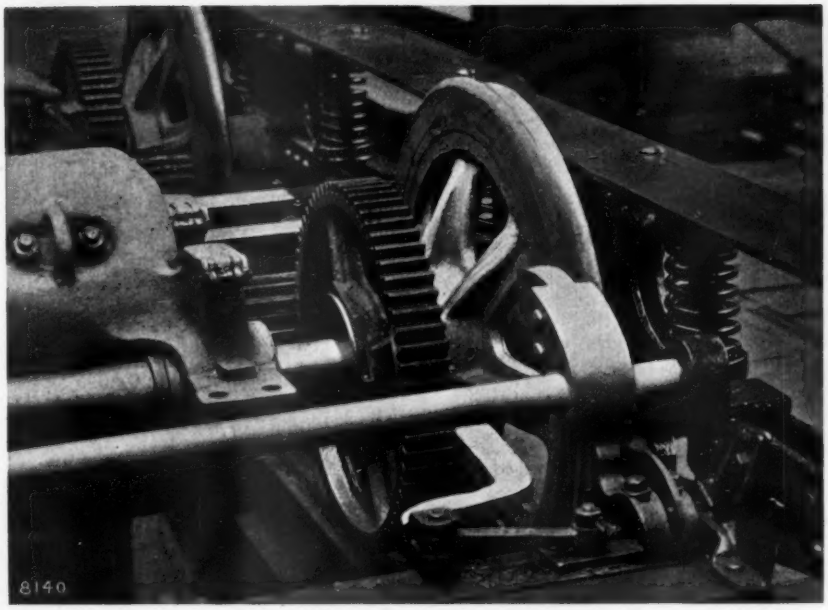


FIG. 6.—THE TRUCK ON 4-FT. 8½-IN. GAUGE, SHOWING DISTANCE BLOCK ON INSIDE OF WHEEL.

wheels. The sleeves or shafts upon which the wheels are mounted move longitudinally upon the axle a distance equal to half the difference between the broad and narrow gauges upon which it is desired the car shall run. The difference between the Bradford and Leeds gauges is 8½ in., thus the amount which each wheel can move is 4¼ ins.

A locking device is provided which consists of four distance blocks suitably mounted. The distance blocks have such adjustments that when the car is on the narrow gauge the distance blocks are on the outside of the wheel, and when on the broad gauge the distance blocks are on the inside of the wheel.

These blocks of course determine the running gauge of the car, and are only provided to keep the wheels on the correct track when going over points.

It might be mentioned that the extreme width of the car is now only the same as before, being fitted with the extensible axles, and is, of course, much narrower than the Leeds cars. The Bradford motormen have thus the same clearances to observe in passing through traffic.

The Causes of Rail Corrugation.

Although the question of rail corrugation is mainly of interest to the tramway engineer, its occurrence on steam railways is not unknown, and in India particularly, "roaring" rails have given much trouble. Numerous theories* have been advanced as to the cause of the phenomenon, but according to Mr. H. B. Nichols, the engineer of way of the Philadelphia Rapid Transit Co., vibration is responsible.

An account of some interesting results obtained by him, of which the following is an abstract, appears in the April issue of the *Official Circular* of the Tramways and Light Railways Association.

The primary cause of corrugations in street car rails, it is assumed here, is vibration, either in the rails or in the entire track structure; that is, the wheels of motor or other power-driven cars have a tendency to skid or slip because of the rapid vibration of the rails, which, by reason of the inertia of the car, the wheels are unable to follow

*ENGINEERING REVIEW, Vol XV. p. 117 to 125.

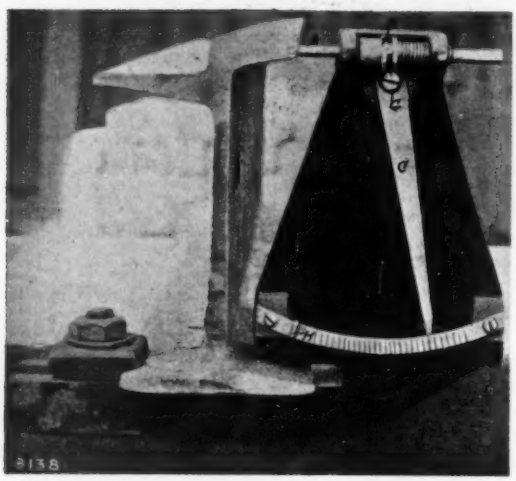


FIG. 7.—INSTRUMENT FOR MEASURING LATERAL BENDING OF RAILS.

instantaneously, thereby causing friction between the wheels and rail to vary in accordance with the wave length of vibration.

The corrugations may arise from any one of four different causes, namely, the vibration or lateral bending of the web of the rail itself; the rails being loose on their supports; the ties being loose on their foundations; the vibration or movement of the foundation immediately under the track structure.

Which one of these defects or conditions causes the corrugations can be ascertained by inspection of the head of the rail. Each condition produces corrugations of a different character, not only in length and form, but also with certain other peculiarities difficult of explanation without referring to a case in point.

The writer has been asked several times why these corrugations do not appear more frequently on steam roads, if they are, as he believes, due to vibration. The answer is, in his opinion, that the comparatively loose rail is forced ahead by the great weight of the locomotive in the well-known long wave, and that there is very little slipping in the wheels of the trailer cars. The writer has had several letters from engineers of foreign roads, describing their troubles with corrugated rails, and has noted that in the most serious cases the rails were supported by chairs or were provided with some form of a cushion. He thinks a careful inspection would show that there is a slight movement between the rail and its supports.

The writer has made quite a number of experiments and trials to verify his theory, and would call attention to one case. About five years ago it was proposed to reconstruct a section of double track about 2,000 ft. in length, using a 90-lb. 9-in. girder rail laid on ties on a gravel base. When the excavation was made, however, the earth was found to be very spongy, consisting of clay and water-bearing gravel. For this reason the excavation was carried about 7 ins. below the ties, and the space filled with concrete to a point 1 in. below the grade of the bottom of the ties. The ties were then carefully tamped with a mixture of fine concrete and the space between them filled to the base of the rail, which was also tamped. An additional 2 in. of concrete were then placed as a foundation for the paving.

After a year's service the rails of both tracks were found to be badly corrugated over practically their entire length, the corrugations being from 1 in. to 1½ in. apart and extending from the gauge line over about two-thirds the width of the head. In order to ascertain the cause of this trouble, the paving and the concrete were removed above the ties, both in and outside the rails, and a careful inspection was made and measurements taken to ascertain if there were any vertical movement in the road-bed or rails, but none could be detected. It was thus evident that if the writer's theory was correct there must be a lateral bending or vibration of the rail itself, and in order to ascertain if this were a fact an instrument was constructed, as shown in the accompanying illustration. It will be noted that the frame may be rigidly clamped to the base of the rail, and that the vertical arm is provided with a piston A carrying a nut B, the piston being forced against the head of the rail by a spring behind the nut. A hand or pointer *C* is pivoted at *G*, the upper end of this hand engaging the nut, the other end resting on a graduated arc. The lengths of the upper and lower arms of the hand or pointer are in the ratio of 10 to 1, each graduation representing $\frac{1}{64}$ of an inch.

In using this machine it is only necessary

to clamp to the base of the rail and set the lower end of the hand at zero, which can be done by turning the piston in the nut. The amount of lateral motion in the head of the rail, due to bending or buckling of the web, will then be indicated by the marker *H*, which is placed against the hand before a car is allowed to run over the rail. In many cases a movement of $\frac{3}{32}$ in. was noted.

In order to further verify the results of this experiment, fish-plates 30 ft. in length were secured and bolted to the outside of the rail, thus giving a support to the head and greatly stiffening the entire rail. After a few months it was found that, on rails equipped with these fish-plates, corrugations were rapidly disappearing. As strengthening the rail in this manner would be too expensive to be practical, it was decided to stiffen the web of the rails by using a special brace on each alternate tie along the outside of the rails. This work was completed a little over a year ago, and a recent inspection shows that nearly all of the corrugations have disappeared.

The Most Economical Mean Effective Pressure for Steam Engines.*

THE development of the reciprocating steam engine has been along the line of higher initial steam pressures. The gain in economy obtained however, with the rise of steam pressures has somewhat obscured the conditions which make for maximum efficiency, for any type of engine using steam at any particular pressure. For an exact determination of the most economical conditions for any type of engine direct experiments are necessary.

From an analysis of the published experiments during the past twenty years the author arrives at the following conclusions :—

1. The higher the mean effective pressure the lower will be the first cost of a steam engine of any given power.

2. For multiple-expansion unjacketed condensing engines, using saturated steam at about 165 lb. per sq. in. absolute in the engine cylinder, the best mean effective pressure for normal load is from 40 lb. to 45 lb. per sq. in. referred to the low-pressure cylinder, and the economy varies but slightly for a considerable range in the mean effective pressure.

3. For jacketed multiple-expansion condensing engines with steam pressure as above, the best mean effective pressure is slightly lower than for unjacketed multiple-expansion condensing engines.

4. Non-condensing engines have a best mean effective pressure rather higher, and the variation in economy for any given range of mean effective pressure is less, than for condensing engines.

5. For steam pressures higher than 165 lb. per sq. in. absolute, the best mean effective pressure is higher than from 40 lb. to 45 lb. per sq. in., and is probably as high as from 45 lb. to 50 lb. per sq. in. referred to the low-pressure cylinder, for triple or quadruple expansion engines using saturated steam over 200 lb. per sq. in. boiler pressure.

6. Multiple-expansion engines using saturated steam below 165 lb. per sq. in. absolute have their best mean effective pressures below from 40 lb. to 45 lb. per sq. in., and this best mean effective pressure falls more rapidly with fall of steam pressure for the condensing than for the non-condensing engine.

7. The more economical an engine can be made, the lower is likely to be the best mean effective pressure, though not to any large extent. Hence large engines may have a rather lower best mean effective pressure than small engines using steam at the same pressure.

8. Engines using highly superheated steam, so that the steam is superheated during expansion, have a best mean effective pressure lower than for engines using saturated steam, with a consequent increase in first cost for any given power. Such engines, however, have a high thermal efficiency, and will maintain the same efficiency over a wide range of power.

9. The best mean effective pressure is about 35 lb. per sq. in. for single-cylinder condensing non-jacketed engines using saturated steam at about 75 lb. per sq. in. absolute. For other conditions the same general laws hold good for multiple-expansion engines.

The most economical mean effective pressure is influenced slightly by the variation of first cost with variation of mean effective pressure, but no particular account has been taken of this. Also, the character of the load—that is, whether variable or fairly constant—will have an influence. For example, an engine which is subjected to frequent and long-continued overloads should have a lower mean effective pressure for normal load than a similar engine which is nearly always working at the normal load.

* Abstract of a Paper, by R. Royds, M.Sc., read before the Institution of Engineers and Shipbuilders in Scotland.

GENERAL REVIEW

LEADING ARTICLES OF THE MONTH—CURRENT EVENTS—TECHNICAL INFORMATION FROM ALL SOURCES.

The Pyrmont Bridge, Sydney, N.S.W.*

By P. ALLEN, M.Inst.C.E.

THE Pyrmont bridge across Darling Harbour replaces the old bridge built by a private company in 1857. The new bridge and its approaches extend from Sussex Street on the City side to Murray Street on the Pyrmont Shore, a distance of 1,825 ft., the length of the bridge proper being 1,210 ft. There are three 30-ft. clear openings in the Sydney approach for vehicular traffic to wharves; while on the Pyrmont side the Darling Island Railway passes under a steel bridge of 25 ft. span. Electrical motive power is used for working the swing-span, also for roadway-gates and lighting, the whole being operated by one man from a conning-tower on the centre of the swing-span. The approaches are imposing in character, owing to the northern, or exposed, sides of abutments and retaining-walls being faced with Pyrmont freestone. The clear headway above high-water mark is 25 ft. under the side spans, which are twelve in number, with trusses of the "Howe" type slightly modified.

The wrought-iron caisson forming the pivot-pier has a diameter of 42 ft., is 53 ft. 1½ ins. in length, and the two concentric rings of which it is composed are connected with angle-bar bracing, the inner ring being splayed out at the bottom to form a cutting edge. It was sunk by open dredging to the rock, which had a dip of 8 ft. in diameter.

The first section, weighing 50 tons, was put together on an ironbark frame suspended by wire ropes from the already-erected permanent protecting platform. The lines were eased off till floating point, when section after section was built on, until the harbour-bed was nearly reached, weighting being done by depositing concrete between the walls. Care had been taken previously to level off the bed, and the caisson was brought to true position by folding wedges between timber guides against the side of the caisson and the piles of the platform. Once grounded, the inside material was removed by means of a bucket dredger until rock was reached. Bores having disclosed 25 ft. of stiff sandy clay, it was intended to excavate in the dry in the sloping rock sufficiently to enable the cutting edge to be bedded on the solid for its whole periphery. When the water was pumped out the caisson listed 11 ins. out of level, but only two small leaks occurred. Excavation proceeded on the high side, the caisson being lowered 2 ft. in forty-eight hours, when a "blow" filled the chamber in twenty minutes, but did not alter the plumb. This was doubtless due to the stiff clay not following the cant, the large head eventually breaking the seal.

The advantage of a dry foundation was considered so great that pumping out was decided upon, despite the alternative of excavating and depositing of the bottom 12 ft. of concrete by divers which had been provided for in the contract. A large bank of clay was put in position and excavation of the remaining 6 ft. of rock in the wet was proceeded with by "jumpers." During excavation the water was kept near the top of the inner wall. Upon rock being cleared about 1 ft., water was pumped down about 23 ft., and the caisson was allowed to settle, this being carried on until the contract-depth was reached. Non-uniformity of strata and any consequent tilting was immediately dealt with, the cutting edge being ultimately bedded in correct position

* Proceedings of the Institution of Civil Engineers, April, 1907.

with its top only 2¼ ins. out of level—well within the margin of 1 ft. allowed. The plumb sides of the caisson and the simple expedient of having four draught-gauges figured on the inner wall materially assisted in achieving this accuracy.

Details are then given as to how concrete was deposited by divers where the cutting edge was not bearing, and how the inside of the chamber was made secure before pumping out. Upon lowering the water only three small leaks were found, which, when led to a sump, could be kept down by hand-baling. Concreting was then carried on day and night up to 12 ft. above the cutting edge. From this point the caisson was filled with rubble sandstone concrete, the plum weighing up to 3 tons. The total weight on the foundation, excluding friction and buoyancy, is 6,800 tons.

The rest-piers are of concrete, with masonry tops, the Pyrmont one being founded on rock, whilst that on the Sydney side is carried on fifty-eight piles driven to the rock 64 ft. below low-water mark. The site for the latter was excavated by a ladder dredge to a level clay bottom 32 ft. below low-water, piles being driven to the rock with a follower, and finished alternately 2 ft. and 3 ft. 6 ins. above this level. Sheathing was then built round, and a box for concreting was formed. After divers had removed accumulated silt, &c., sand was deposited over the whole area to obtain a clean bottom. The method adopted for depositing concrete (1,850 cubic yards in 19 days) through water by special tripping boxes, and for overcoming "slurry" are fully described.

The four N-shaped main girders forming the swing-span have horizontal tops with curved bottom booms, and are 223 ft. in length, with a depth of 15ft. at the centre and 5 ft. at the ends. Owing to the high speed of swinging, a rigid deck span was essential, which was obtained by riveting the buckled plates to the projecting bottom flange-plates of the top booms. The swing is of the rim-bearing type, its weight of 850 tons when swinging being distributed by means of small girders to equidistant points on the drum.

Great ingenuity was displayed by the supervising engineers in England in arranging for the treads and tracks of the turntable to be faced up true, the diameter (35 ft.) being so large that provision for turning could not be given effect to without building special lathes. The method adopted is fully described. When the parts were erected the sections fitted accurately, and the fact that the span has coasted 70 degrees after cutting off the current shows the easy running of the track.

Difficulty was experienced through the pivot moving, and owing to the rollers seizing and tearing off the ends of the radial rods. The steps taken to overcome these defects, which became serious, are fully detailed. The results were gratifying, for in the three years after effecting these alterations the swing-span was opened 18,816 times without a hitch or any expenditure for repairs, whilst there is not an idle roller, thus showing complete distribution of the weight.

The electrical equipment for operating the swing-span consists of two 50-h.p. motors, located on a machinery platform within the drum, and driving a main horizontal shaft connected by vertical shafts and bevel-gearing to the rack at the top of the pier. The motors have a guaranteed starting effort of 5,384 lb. at 3·143 in. radius from the centre of the armature-shaft; also an armature-speed of 509 revolutions per minute in 24 seconds with load, and current not exceeding 130 amperes in either motor. Results are given of exhaustive tests made of the power and cost for opening the span. The quickest opening was 30 seconds, costing 0·357*d.*; while the most economical run took 55 seconds, costing 0·192*d.*, with a maximum effort of 48 h.p.

Tables show the cost and speed of lifting the ends of the span and working the gates; while a full description of the working is given, together with details of the design of the controlling brake and the latch and catch for securing the span. The motor-gear and solenoid brakes for the gates are also described, with an account of the difficulty experienced before obtaining satisfactory results.

Current is supplied by the Railway Commissioners at 1*d.* per Board-of-Trade unit. During the 4 years 1902-1906, the swing was opened 24,610 times, the cost of the current being £83 6*s.* 5*d.* The total cost of the work was £112,500. The bridge was begun in 1899, and opened in 1902.

Veneer Cutting Machinery.*

The veneer industry is not a modern one, since veneers have been produced since the early days of the circular saw; but in all parts of the world people are awakening to the fact of the growing scarcity of the finer

* *Sibley Journal of Engineering.*

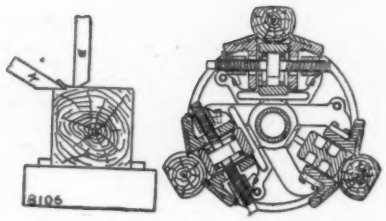


FIG. 1. FIG. 2.

VENEER CUTTING MACHINERY.

woods, such as mahogany, Spanish cedar, and the figured oaks. The growing need of economy has been the prime factor in modernising the veneer industry and making it an interesting and profitable field for the engineer.

By the old method of cutting veneers with a circular saw, if perhaps a veneer was to be cut the thickness of the saw, more than half of the available lumber went as sawdust, and still more was lost in sand-papering and polishing down to the finished product. This method is still followed for the larger veneers, say from 15 ft. to 18 ft. long; but the economy of the slicing machine, which carries a long knife and with it peels or slices the log, becomes apparent since the slicer uses all the available wood and gives almost a finished product.

The apparent practical limit of knife length has been about 14 ft., and this, of course, limits the size of the machine, although larger knives have been made in sections; but veneer machine-builders are beginning to realise that an 18 ft. machine will be as superior to a 10 ft. machine as an 18,000-ton battleship is superior in power and efficiency to a 10,000-ton ship. So the problem of length and necessary strength is the one now facing such engineers if they desire to cut longer and finer veneers on a more economical basis.

Veneer slicing machines are roughly divided into two classes—rotary machines and simple slicers. In the rotary machine the round log to be cut is placed on spindles, which grip it at the ends and revolve it about its axis into a stationary knife, which is fed horizontally toward the centre of the log, thus taking off a long slice which is afterwards divided into smaller sections and dried, the log having been previously boiled thoroughly so as to avoid breaking or crumbling, as would be the case if it were cut dry. By this method a small, round log, somewhat larger than the dogs or clutches in the spindle, is left. The disposition of this will be spoken of later.

In the slicer the log which has been sawed square is fastened, dogged to a stay log which moves in a vertical plane with rotary motion or motion imparted by guides, so that as the log is brought down on the knife it will have some lateral as well as vertical motion. The knife must be fed up for each stroke, and kicked back to clear the log when it is raised for the next stroke. The feed must be delicately adjusted, and must have no lost motion, in order to secure uniform thickness. A machine recently built for the Singer Sewing Machine Company's veneer plant at Cairo, Ill., on its first test was easily made to cut 120 veneers per inch of log, and a duplicate machine afterwards cut 140 to an inch. The one remarkable thing, however, about these performances was the fact that only a very small percentage of the veneers cut were spoiled by uneven cutting. This leads us to a most important feature of the machine—the pressure bar, without which accurate cutting could not be accomplished, as it is almost impossible to fasten the soft log securely enough to obtain an even cut. The pressure bar *B* shown in sketch Fig. 1 is a flexible bar placed, just a hair's breadth less than the thickness of the veneer required, behind the edge of the knife *K*, so that the knife may enter the log only at the required thickness. On the machine referred to, this bar is adjustable, both vertically and horizontally, to exactly follow the motion of the knife if the latter should happen to be ground unevenly. The expert operator will know how much compression to use, what bevel to give the knife, and from the nature of the wood whether to set the knife vertically or head it into or out from the log by some slight angle. The grain of the log must be studied, so that when put on the stay log it will always be cut, as nearly as possible, crossgrain. The knife invariably has a tendency to follow the curls in the grain, and, of course, the better this is overcome the finer will be the figure of the wood.

A recent article in the "Scientific American" called attention to the fact that the large proportion of the veneer used in the United States and in Europe is cut on rotary machines, and the small log which is left after cutting down to the diameter of the spindle is either used for firewood or piled up and allowed to rot. There is much valuable lumber in these logs which would be suitable for panels and pieces of furniture. Strange to say, only during the last year has any attempt been made to produce a machine to cut up these formerly wasted logs. A device invented by Mr. E. F. Smith,

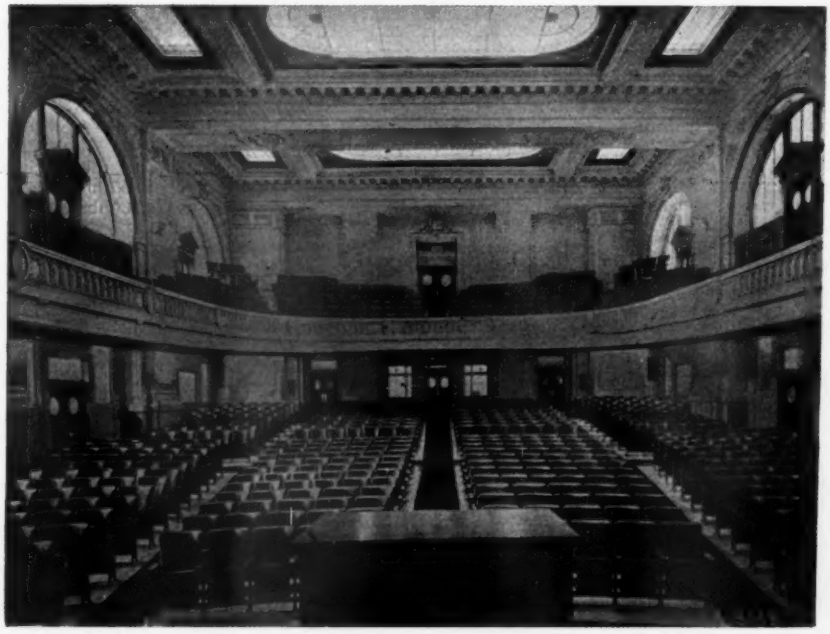
of the Edwin F. Smith Company, Philadelphia, and now about to be tested, has been designed to fit on to a rotary veneer machine, taking the place of the large log, and being supplied with three stay logs or dogging-bars to secure the small logs, which are then turned on to the knife and may be cut down to the thin slab necessary to dog the log. Fig. 2 shows a modification of the above-mentioned rotary stay log with the logs in place. The larger veneers running near the centre of the log, will be of a fair size, and in the case of oak, where the wood is cut parallel to and through the medullary rays which radiate from the centre of the log, thus giving the familiar figure of quartered oak, which greatly enhances the value of the wood.

The veneer industry offers an interesting field to the engineer for inventive and experimental work. It offers the satisfaction and opportunity for working along the lines of advancement and development—a long definition of success.

The chief use for veneering is indicated by its name—a covering for baser things. This definition might not hold in an atmosphere of breeding and etiquette; in this case it might be defined as a thin layer of fine wood glued over a cheaper, coarser wood, thereby giving a pleasing appearance, and in some cases greater durability, particularly with mahogany, where the tendency to warp is often overcome by gluing together thin layers or veneers with the alternate grains at right angles. The finest modern furniture is made in this way.

The Engineering Societies' Building in New York.

An example which might with advantage to all concerned be followed by the leading British engineering societies, where headquarters are situated in different buildings in London, has been set in New York by the American Society of Mechanical Engineers, Institute of Mining Engineers, and the Institute of Electrical Engineers, together with other technical organisations who have joined together in the establishment of a general



MAIN AUDITORIUM IN ENGINEERING SOCIETIES' BUILDING, NEW YORK.

headquarters. Accommodation has thus been obtained which would probably not have been within the reach of any particular organisation, for not only has each of the three founder societies mentioned above a floor laid out in accordance with its own plans devoted to administrative and executive work, but a general auditorium is provided capable of seating 1,000 persons. How far the latter surpasses any of the lecture rooms of our own institution buildings in comfort, accommodation and appearance, the accompanying illustration will reveal. A further feature is that the libraries of the various societies have been concentrated, while there are further provided two large assembly rooms, a number of small lecture halls, committee rooms, a refreshment department, and a museum.

The building, which is 13½ stories high above the pavement, utilises 115 ft. of the 125 ft. frontage and 90 ft. of the 100 ft. depth. It is a handsome structure of stone, steel and light-yellow brick and terra-cotta. More than £340,000, including the cost of land, has been expended in its erection, of which sum £210,000 was given by Mr. Andrew Carnegie to cover the immediate cost of construction.

The woodwork in the building has been reduced to a minimum. Many of the window frames are of cast-iron, and the others, of wood, are covered with kalamined iron. All the doors in the basement, first floor and at the ends of the auditorium promenade, are kalamined-iron fire doors. The windows up to a height of 100 ft. (the building being 218 ft. 6½ ins. high) are glazed with wire glass except on the Thirty-ninth Street front. As an extra precaution against fire an 8,000-gallon tank has been placed on the roof, with a standpipe at each end of the building, the tank being fed by two electric pumps. All the walls and ceilings are painted in neutral tints and the decoration is simple.

Steam is employed for heating and ventilating purposes, generated at low pressure by three boilers of the wrought-steel header type, of Babcock and Wilcox manufacture, having an aggregate of 5,226 sq. ft. heating surface. The boilers, as well as the valves, piping and attachments in connection with the boiler plant, are designed and arranged for high-pressure steam.

The heating is accomplished by low-pressure steam circulating through radiators placed underneath the windows. Pure, fresh air in large quantities is supplied to all the rooms and the main corridors in the lower six floors by means of four electric-driven "Sturtevant" blowers, located in the basement. Air is exhausted from these floors and from the basement throughout the building by means of four electric-driven "Blackman" exhaust fans, located in fan-houses on the roof.

The electrical current supply is derived from an outside service, and both alternating and direct-current are available. Space has been provided, and the steam and electric equipment have been designed so that an electric generating plant may be installed at any time.

In order to provide ample current facilities for demonstration purposes, special feeders have been run from the switchboard in the basement to the auditorium and to each of the assembly and lecture rooms. The connections of these feeders at the main switchboard in the basement are such that any desired arrangement or combination of the conductors may be made and, if desired, connections for either direct-current or alternating current, single phase, two-phase, three-phase, may be quickly made.

Test of a 3,500 k.w. Turbo-Alternator.

The following are the particulars of a test recently carried out by Mr. C. H. Merz on one of the four 3,500 k.w. turbo-alternators supplied by Messrs. C. A. Parsons & Co. for the Carville Power Station of the Newcastle Electric Supply Co., Ltd. :—

The trials were made after the machine had been at work for over six months, and the results obtained, viz., 13·189 lbs. per k.w. hour, which is equivalent to 7·85 lbs. per i.h.p., constitutes probably a record in steam efficiency.

These turbines are fitted with a steam automatic bye-pass, so that the turbine may deal with large overloads for traction and train work, and the tests show that a very high efficiency is maintained over large ranges of output.

The following tests were made :—(1) No load (non-excited) ½ hr. ; (2) no load (excited) ½ hr. ; (3) 2,000 k.w., 1 hr. ; (4) 4,000 k.w., 1½ hr. ; (5) 6,000 k.w., 1½ hr. ; (6) 7,000 k.w., ½ hr. ; (7) 5,000 k.w., 1 hr.

Loads were kept as nearly constant as possible throughout by means of the exciter field rheostat.

The weight of condensed steam was measured by the Company's tank and weigh-bridge, which had on the day previous to the test been calibrated in presence of H.M. Inspector of Weights and Measures and certified correct. The vacuum was measured

at the turbine exhaust chamber by a mercury column. Steam temperature and pressure were taken at the turbine stop valve. The speed was taken by tachometer. In the final consumption results only the actual output of the generator has been taken into account, no deduction being made for any auxiliaries. The field current of the exciter was supplied from an entirely independent source, but apart from this the machine provided its own excitation. The neutral point of the generator windings was disconnected from earth, and the three phases were loaded by means of a water resistance.

The output of the machine was measured by a special wattmeter, and by the switchbroad integrating wattmeter. The current was measured by a special ammeter connected to the same current transformer as the special wattmeters, and by the switchboard ammeter. These instruments were connected in different phases, giving the balance of load between phases. An ammeter was also placed in the exciting circuit. The switchboard voltmeter, indicating wattmeter, and power factor meter were in circuit, and were read every five minutes to check the accuracy of the wattmeter. The special instruments and the switchboard integrating wattmeter were all carefully calibrated both before and after the test, and corrections were made in the measured output in accordance with the mean of the observed errors at the before and after calibrations.

A whistle was sounded at the commencement and finish of the test, the first reading being immediately taken at the whistle and thereafter at intervals of five minutes. The lift pump discharge valve was at the signal closed to the hotwell and opened to the weigh-tank.

To verify the steam consumption at the most economical load, a further test, consisting of three hours' run at a load of 5,000 k.w. was held under the same conditions as before. The figures obtained are shown on the table as test No. 8 and corroborate the previous tests, the slightly poorer results being due to the less superheat.

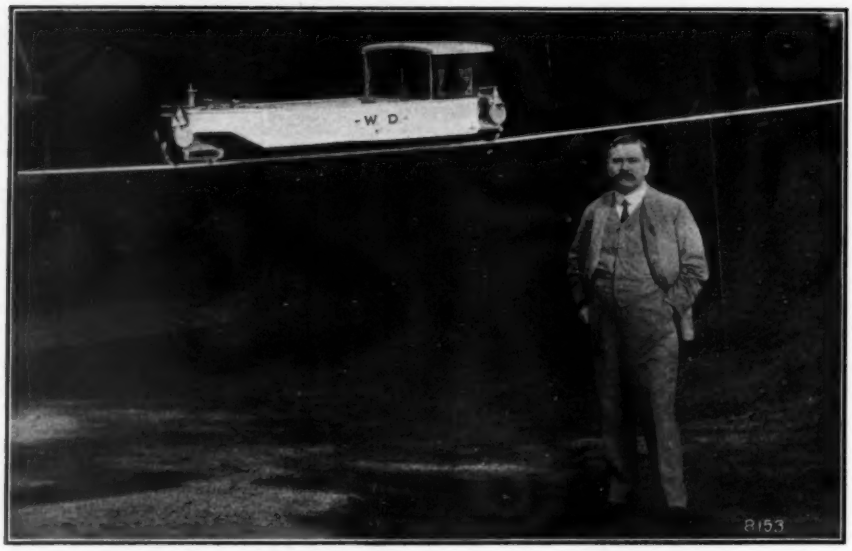
The Brennan Mono-Railway.

By the courtesy of Mr. Louis Brennan, well known as the inventor of the torpedo bearing his name, we are able to present an illustration of a model mono-rail car or locomotive which formed a conspicuous and interesting exhibit at Burlington House.

The feature of the system is that equilibrium is maintained by gyroscopic action whether the car be standing or running. As will be seen, the centre of gravity is above rail level and consequently, being an unstable body, the car would in the ordinary way topple over. This tendency, however, the gyroscopic action effectually prevents, and in fact the phenomenon of precession was prettily demonstrated by the model when, after a weight had been placed one side, the vehicle was not depressed in a lateral direction as would at first be expected. A simple illustration of this action may be found in an ordinary child's hoop. If the latter be rolled along it develops a tendency to tilt over, or in other words takes on a precessional motion. If one endeavours with a hoop stick to turn it more quickly to the left, the hoop at once rises to a vertical position.

The car is carried on two bogies, one at each end, the bogies being pivoted both vertically and horizontally, permitting the negotiation of curves on uneven ground without risk of derailment. This feature was successfully demonstrated at the meeting, the model which was run on a length of a single track and tightly stretched wire rope, taking sharp curves with the greatest ease, leaning inwards at the curve and rising to the

Test No.	Duration (Hours).	Mean Calibrated K.W.	Steam.			Speed R.P.M.	At Turbo Exhaust.	Water.		
			Pressure.	Temperature at Turbo. °F.	Superheat °F.		Vacuum at 30" Brm.	Total Condensed Lbs.	Lbs. per Hour.	Lbs. per K.W. Hour.
1	½	No load not excited.	180	460	80	1,200	28·875	1,835	3,670	—
2	½	No load excited.	211	453·3	61	,,	28·95	2,603	5,206	—
3	1	2192·87	202·4	492·1	103	,,	29·036	31,836	31,836	14·517
4	1½	4045·14	197·4	495	108	,,	29·066	83,972	55,981·3	13·839
5	1½	5901·	195·8	503·2	117	,,	28·95	119,182	79,454·6	13·464
6	½	6921·8	198·4	505·5	118·5	,,	28·765	47,390	94,780	13·692
7	1	5164·07	199·9	506·5	120·5	,,	29·039	68,180	68,180	13·189
8	3	5059·38	194·5	477·9	92	,,	29·195	203,559	67,853	13·411



THE BRENNAN MONO-RAILWAY.

vertical on coming into the straight again. Propulsion is effected by current derived from a number of accumulators carried on the car, the energy being utilized by electric motors driving through gearing one of the two coupled wheels comprising each bogie.

As above stated the car depends for equilibrium on the action of two gyroscopes which rotate in a vertical plane in opposite directions.

These are geared together to ensure uniform velocity being obtained, and run in special bearings in a partial vacuum at a speed of from 7,000—8,000 revolutions per minute. The driving is by electric motors taking current from the accumulators carried on the vehicle. The energy stored in the gyroscopes is sufficient to maintain them in motion for a considerable time after current is cut off, so that in the event of a failure of current the car would continue in equilibrium for a sufficient time to allow legs to be put out to support it.

The gyroscopic mechanism occupies but little space and in full-sized cars is only 5 per cent. of the total weight of the vehicle.

The photograph shows the vehicle crossing a 50 ft. span of the model railway erected in the grounds of the inventor's house at Gillingham, Kent, where demonstrations were given to show the utility of the system for military purposes.

The Specific Heat of Superheated Steam.

REPLY TO PROF. ROBERT H SMITH'S CRITIQUE.*

By S. B. BILBROUGH, B.A

IT will be as well to reply to Prof. Smith's critique in detail at once on account of the distance separating us.

It was preferable to give the actual readings exactly as registered as data during the experiments, whether in °C. or °F., on account of defining the size of the thermometer graduations. Otherwise all the Cent. readings are converted to Fah. As only the *difference* of the readings was of importance, it was not necessary to give the actual absolute reading, because this would have implied that the absolute readings were correct to the second decimal place, whereas it is only the difference that has that degree of accuracy.

The specific heat when used unqualified is always that at constant pressure, even though the pressure varies; it may seem paradoxical, but it is only apparently so when the conditions are examined closely.

On the next point I am entirely in agreement with Prof. Smith, and, to my surprise, he interprets my very meaning as if it were contradictory to what the experiments themselves prove. I am fully aware that K cannot be a constant and equal to ·305 outside his dotted limit curve, unless Regnault's equation for saturated steam is exactly linear. As his linear equation has been used throughout, it had to be taken that K was constant beyond the limit curve, though it is contrary to the experiments, which show there must be a variation, over large pressure ranges. My point is this, and I have never lost sight of it: Beyond the limit curve or point of no variation—*i.e.*, where Joule's law is obeyed—

$$dH\ d\theta \text{ must } = K.$$

The proof of this is surely quite logical as follows:—

Given that a change of pressure produces no change of temperature in superheated vapour, which maintains its total heat constant.

Then the rate of change of total heat in the saturated portion of the vapour, per degree of saturation temperature (corresponding to the change of pressure) must equal the rate of change of heat in the superheated portion, per degree of temperature, *i.e.*

$$dH\ d\theta = K.$$

And since Joule's law is obeyed over large changes of pressure, and the value of ϕ or γ varies for such pressure changes, then $dH\ d\theta$ or K must vary to balance the variation of ϕ because the total heat remains constant.

Therefore $dH\ d\theta$ or K cannot be exactly a constant.

It is not the writer's "idea," nor does he "assume implicitly" that K is always a constant beyond the limit curve, in view of the fact that ϕ is a variable.

However, on looking over the paper again, there appears good grounds for Prof. Smith's misinterpretation, as the above point is not definitely stated, though often hinted at.

I am glad to see his lucid explanation, using as co-ordinates pressure and temperature. It illustrates very clearly the behaviour of the steam. The co-ordinates in the paper—namely specific heat and temperature—were used, because area then represented heat units.

Prof. Smith shows that the isobaric specific heat outside the dotted limit is only a very rough average and is 10 per cent less than ·305 or say, ·27, but if we begin at the other end it can be shown to be 10 per cent. more or say ·33.

Hence, to calculate the average values of K at the two pressures, atmospheric and 150 lbs., p □″, the respective values of ϕ for each pressure were used, and $dH\ d\theta$ has been taken = ·305 for both high pressures and atmospheric.

What better method can we employ with Regnault's linear equation?

The method employed by Prof. Smith, p. 164, showing that $K = ·305\ \frac{t'_2 - t_2}{T' - T}$ could not be used for the above reason.

There is one slight error p. 164; Y should = ·305 $(t_2 - T)$. Also in the February No.,

* THE ENGINEERING REVIEW, Vol. XVI., pp. 104 to 124, and pp. 161 to 165.

p. 108, column 1, thirtieth line from top should read

$$= Y + \cdot 305\,(T_1 - t_1).$$

The factor $(t_2 - t_1)$ occurs so often that at first sight it appears to be quite correct.

The writer quite expected criticism on the high values of K near saturation. Fortunately the experimental data for these results were far the most accurate and easiest to obtain.

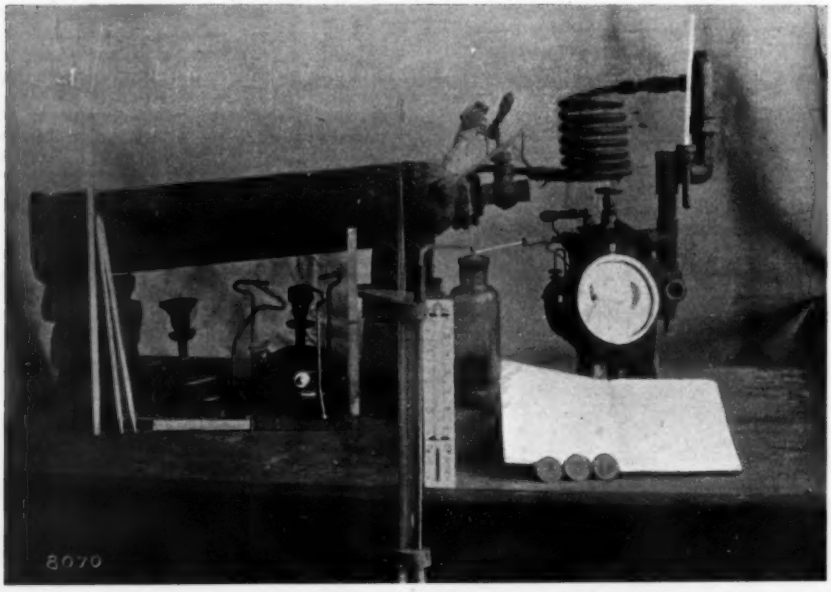
"The experimentally measured differences of temperature," though fairly small, were large compared to the accuracy of the thermometer. The actual rise was about 1·2° C. (Table VIII.) for a change of pressure of 1·17 of mercury. This means the temperature rise extends over 12 divisions or graduations on the thermometer stem. This cannot be called "very small."

This change of temperature, too, was always definite and rapid, indeed, instantaneous with any pressure change.

And again, the reference to "steam properties and gauge pressures" perhaps needs further explanation. The rise in temperature of the saturated steam due to a rise of pressure was in all cases known actually on the very thermometer used, being determined experimentally before the steam was superheated; and in all cases $\frac{dt}{dp}$ agreed with the figures in standard tables, except at one part of the thermometer where a correction was made. This correction was extremely small and applied to only three tests—viz., Nos. 49, 50, and 51. Some have dT exactly on the same scale as dt, and the size of the degrees used were equal to those used by Regnault, both being referred to the air thermometer.

The experiments were not "too rough to give credence to so improbable a set of figures." Prof. Smith gives the usual explanation of unevaporated water being in the steam. It would be unfair not to give the credit to D. K. Clark for the following forcible argument (*The Steam Engine*, vol. i., p. 24):—

> "It is thought that the rapidity of expansion by heat, near the boiling point, is to be accounted for by the supposed insensible moisture of steam in the saturated condition, as generated from water, being evaporated and contributing to increase the quantity of steam without raising the temperature. This argument is



S. B. BILBROUGH'S APPARATUS USED FOR DETERMINING THE SPECIFIC HEAT OF SUPERHEATED STEAM. LAGGING AND SUPERHEATING COVER REMOVED.

plausible; but it might be argued, on the contrary, that in the converse process, of abstracting heat from superheated steam, the the accelerated reduction of volume when it approaches the point of saturation, is due to incipient condensation, which would be absurd."

Now in all these experiments both processes were employed for each test, and certainly to imagine incipient condensation in the converse process would be absurd. And yet both these processes agree in these experiments and show particularly good agreement near saturation (see Tests Nos. 44-48).

Whatever it is that causes these abnormal figures near saturation, it is certainly due to an intrinsic property of the steam itself and cannot be separated by any mechanical means. Is not the large figure for the latent heat of H_2O due entirely to molecular attractions? Why then should these molecular forces suddenly cease at 1° of superheat? The wonder is that they have all vanished at 16° F. and at 3·5° F. superheat at high pressures. "The Regnault reputed saturation point" is the most definite, exact, and invariable point or line we have among the properties of steam.

Prof. Smith's three general objections to the throttling method conclude his critique:—

1. The effec of *difference* of kinetic energy is quite negligible. The proof of this is simple—both large and small changes of pressure cause no variation from Joule's law; but since the kinetic energy of flow is different for each change of pressure, it should therefore effect a variable deviation from Joule's law, or else can only be a negligible quantity.

2. Neglecting the kinetic energy, the total heat (H), *i.e.*, $E \times p\,v$ as determined by Regnault is a constant. The internal energy in all probability is also constant, but for this $p_1 v_1$ must equal $p_2 v_2$.

3. The steam does not impinge directly on the thermometer or its casing, and if it did so, would not the *difference* in impinging effects be negligible? And the proof that it is so is the same as for the negligible difference in kinetic energy, in case No. 1.

The same argument applies to any difference in rate of flow pointed out by Prof. Smith in tests Nos. 20 and 24 of the paper. It is very unlikely that errors due to kinetic energy, diminished flow, and impingement on the thermometer are always going to exactly balance either each other or any deviation from Joule's law and so maintain the temperature a constant, when the changes of pressure vary from a few inches of mercury to say 50 lbs. p. $\square''$, and the temperatures range from 220° F. to 800° F. In all cases Joule's law is obeyed, and therefore the above minor errors show themselves to be too small to have any effect whatever on the thermometer.

In conclusion, I must tender my sincere thanks to Prof. Smith for going into an ambiguously expressed paper so fully. I much regret any ambiguity in expression, and it is a fault only the reader can show up. To the writer all seems clear—naturally—and it is often difficult to express an idea so as to be intelligent to others when the idea has been for a long time almost a continual part of the writer's mind.

ELECTRICAL ENGINEERING NOTES.

By ANDREW STEWART, A.M.I.E.E.

Electrically Operated Ordnance Mechanism.

The paper read by Mr. MacKechnie to the Institute of Naval Architects raises a question of considerable interest to engineers engaged in warship design and construction. As is well known, the United States Navy, and more recently the German Navy, have used electrical apparatus on board their warships to a considerable extent. We have, of course, a large and increasing amount of electrically operated auxiliary machinery on modern warships, but gun mechanism has hitherto been considered the exclusive province of hydraulic power.

Some more recent cruisers have electrically operated gun training gear, but it appears that electrically operated mechanism, while excellent in general performance, is heavier, and therefore less desirable than hydraulic machinery.

The subject in general was dealt with at some length in these notes in our issue of October, 1905, but Mr. MacKechnie's paper raises the question particularly in connection with gun mountings, and the conclusions leave one with the impression that electricity has fewer advantages than was anticipated.

This may be due to the fact that too large a margin has been left to the electric motors, *i.e.* their weight, in view of the intermittent nature of the work, might be still further reduced; moreover, many of the comparative weights of electrically and hydraulically operated gun mechanism were really unfair to the electric drive, as they represented an electric system applied to a hydraulic mounting. If an electric system with its gearing is designed as a complete apparatus to effect a given purpose, very considerable reductions can be effected over any arrangement which represents merely a modification of an existing arrangement.

Much of the work on a warship involves a considerable effort for a few seconds only, and comparatively small power thereafter; for this class of work the electric motor is admirably adapted, as one of its characteristics is ability to exercise much more than its rated power for short periods, so that small motors may be installed, and the characteristic already mentioned may be relied upon to take the heavy starting load.

Hydraulic mountings, on the other hand, must have a cylinder capacity equal to the maximum load, as of course, apparatus depending upon the area and volume of a piston, is inelastic so far as overloads are concerned.

This feature is evident, for, according to Mr. MacKechnie's figures, the horse power of the hydraulic apparatus is sometimes double that of the electric gear; for instance, the central gun hoist in one of his examples is fitted with 30 h.p. hydraulic gear, but only a 15 h.p. electric motor is applied to the same purpose.

A chain rammer has a hydraulic press of 12 h.p., but with electric power a 6 h.p. motor is sufficient.

It is quite true that there are many

difficulties in the way of applying electric power to gun mechanism; but electricity is the new comer, once there has been more experience with electric operation, the difficulties will not seem so formidable as they now appear, while the apparatus for absorbing the recoil of the gun, one of the most difficult things to do electrically, need not be interfered with at all, as it is not essentially hydraulic, nor is it usually connected to the hydraulic equipment of the ship. With the recoil of the gun, a mixture of glycerine and water passes from one side of a piston to another, through a special valve. This part might be retained and an electric motor used for returning the gun to its firing position in place of the usual hydraulic gear.

Most, if not all, difficulties are due to the youthfulness of the new system and the nature of the work, which obviously calls for experience of a kind not easily obtainable, and not paralleled by any other industrial application of electric power.

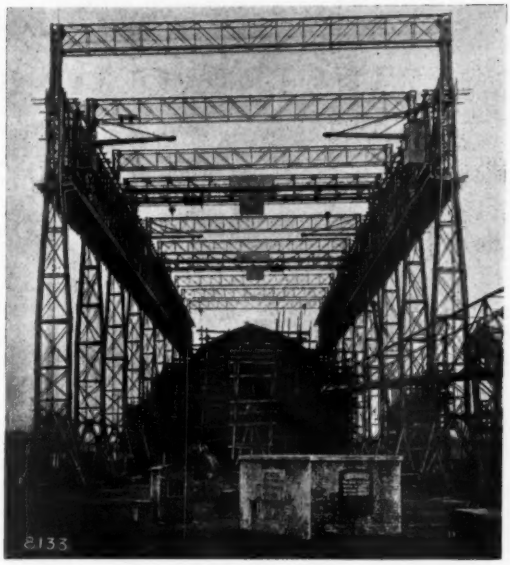


FIG. 1.—BERTH EQUIPPED WITH OVERHEAD TRAVELLING CRANES AND SIDE WALKING CRANES.

Electrically Operated Shipyard Cranes and Derricks.

Shipyards have always been about the most easily discovered industrial establishments as the wood pole derricks were generally a conspicuous feature of the landscape. Those of our readers who saw the *Mauretania* under construction at Wallsend, were no doubt impressed with the structure over the building berth, and the excellent crane service provided as well as *inter alia*, the absence of the usual pole derricks. Messrs. Beardmore's yard on the Clyde provides another example of a modern shipyard equipment on similar lines. Fig. 1 shows one berth equipped with overhead travelling cranes and side walking cranes, which replace the pole derricks hitherto employed. These equipments were supplied by Messrs. Appleby's, Ltd., a combination of two well-known firms, Messrs. Jessop & Applebly, Ltd., and the Glasgow Crane and Hoist Co.

The building berth is spanned by lattice girders supported by braced steel poles: At Messrs. Swan, Hunter and Wigham Richardson's, the lattice girders are replaced by a roof, so that there is less lost time due to inclement weather.

The side walking cranes are constructed for a load of five tons, at a radius of 30 ft. They run, as will be obvious, on a single rail at the bottom, and an overhead guide 24 ft. higher up. They

FIG. 2.—CANTILEVER CRANE.

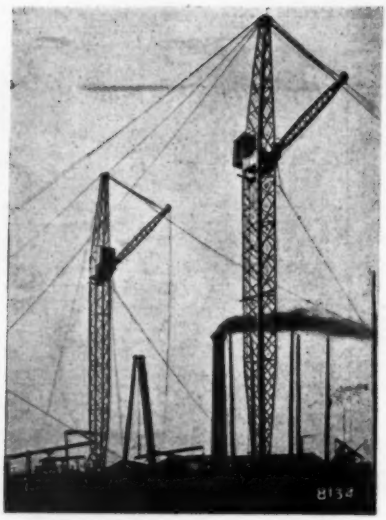


FIG. 3.—ELECTRICALLY OPERATED DERRICKS.

are three motor cranes, having one motor for each motion, viz., lifting, travelling, and slewing. The first of these is of 30 h.p., giving lifting speeds varying from 60 ft. per min. at full load to 160 ft. per min. at light loads. The 20 h.p. travelling motor gives a full load travelling speed of 250 ft. per min., while the slewing gear which has a 5 h.p. motor, gives a speed at the point of the jib of 300 ft. per min.

The overhead travellers, which have a span of 108 ft., are designed for a normal working load of fifteen tons. The lifting motor is, in this case, of 50 h.p., and gives a lifting speed of 41 ft. per min. with full load, and 100 ft. per min., light.

The travelling motor is of 30 h.p., giving a full load travelling speed of 500 ft., and a light load speed of 750 ft. per min. The whole gantry is 750 ft. long. The cross traverse is operated by a 10 h.p. motor, at 220 to 350 ft. per min.

Another crane in the same yard is a five-ton cantilever crane, used chiefly for handling and stacking ship plates.

It is shown in Fig. 2 and is fitted with two motors, one of 50 h.p. lifting and traversing, the former at 100 ft. the latter at 400 ft. per min.; the other, also of 50 h.p., is for travelling at 300 ft. per min. This crane runs on a double line of rails 25 ft. between centres. The wheel base is slightly over 50 ft.

The horizontal girder is, as will be seen, of very light construction, with a view to reducing wind pressure which, in a crane of this type, is important.

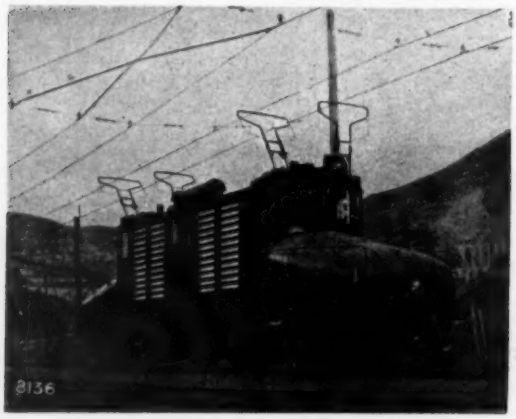


FIG. 4.—SERIES SYSTEM ELECTRIC LOCOMOTIVE.

A still more interesting hoisting gear is now in use in the adjacent shipyard of Messrs. John Brown & Co. These are lattice girder work derricks designed and constructed by Messrs. Sir William Arrol & Co., Ltd. They are illustrated in Fig. 3.

The pole is 130 ft. long by 6 ft. square at the middle; it tapers to 18 ins. square at either end. The jib is of similar construction, and joins the main mast about 95 ft. from the ground level. These derricks are placed at intervals of 100 ft. down the berth, and serve a radius of 35 ft. The peak of the jib is normally

about 120 ft. from the ground level, and five-ton loads can be lifted at 90 ft. per min.

The motors are 35 h.p. for lifting and 10 h.p. for slewing.

A Series Electric Traction System.

In our last issue we referred to Mr. Highfield's paper to the Institution of Electrical Engineers, on the direct-current series system, and we now give a few particulars of a short line of railway in the South of France, operated by this system. The line handles the mineral traffic in the valley of the Motte, and it has several heavy gradients which are, however, with the load, as the return trains consist chiefly of empty wagons. Fourteen miles of the line has a gradient of 1 in 36.

The locomotive is illustrated in Fig. 4 and is operated by a three-wire system at 2,400 volts. maximum pressure. It gives 500 h.p., and is mounted on two four-wheeled bogies, each axle of which carries a motor of 125 h.p. This motor, which is illustrated (Fig. 5), does not differ much from the standard direct-current traction motor. There are two trolley wires having a difference of potential to the rails of 1,200 volts., *i.e.* 2,400 volts. between the two overhead wires, the rails being the neutral.

Current is supplied to the line by the Société Grenobloise de Force et Lumière,

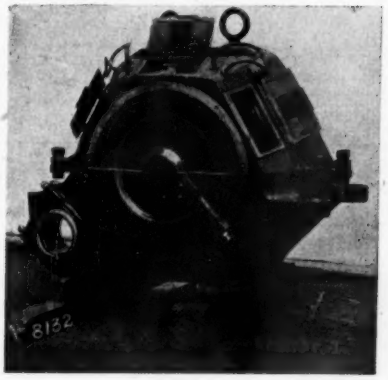


FIG. 5.—TRACTION MOTOR, SERIES SYSTEM.

who have a water-power plant on the River Drac, and is charged, not at a fixed sum per horse-power demanded, as is common with many foreign water power plants, but is metered in the usual way. The train consists of 20 loaded cars weighing 330 tons on the down journey, and an equal number of unloaded cars, weighing 120 tons, on the return journey.

It appears that the energy spent is ·077 units per ton mile of gross weight, including the locomotive, which weighs fifty-five tons.

The generating plant consists of two generators each giving 300 k.w. at a pressure of 1,350 volts., connected in series, and driven by a water turbine at 250 revs. per min.

NOTES AND COMMENTS.

CONSIDERABLE inconvenience and loss has been caused to British manufacturers on account of the recently imposed taxes levied by some British Colonies on catalogues received through the post. Confusion has arisen both in regard to the nature of the packages to be taxed and the methods of collecting the taxes. In some cases there exist no reasonable facilities for paying the duties before the packages are posted, and this has resulted in a very large number of catalogues being undelivered and returned or destroyed, with consequent loss of business to British firms. We are informed that during the past few months the Manufacturers' Association of Great Britain have received several hundreds of enquiries from members and others in regard to the matter, and that that body are now making representations with a view to inducing some of the Colonial Governments to adopt more convenient methods of collecting these taxes. Meanwhile the Manufacturers' Association have prepared a memorandum respecting Tariff Duties for the guidance of manufacturers, from which the following information on the subject is taken:

In agreement with the Customs Union Convention of 1906, there is a common tariff for the Cape of Good Hope, Natal, Orange River Colony, the Transvaal and Southern Rhodesia, under which the duty on catalogues, price lists, &c., has been fixed at the rate of 25 per cent. ad valorem, or 2*d*. per lb., whichever may be the greater, except when the packets are less than 8 ozs. in weight, in which case they enter free. The tax is collected as a surcharge, there being no arrangements at present for paying it in Great Britain, and the best method to adopt when forwarding catalogues through the post is to remit the duty on each packet to the postmaster-general in the capital town in each Colony, and mark the package "Duty paid to the Postmaster-General." As, however, English stamps will not be accepted in payment of duty, a postal or money order must be remitted.

The Australian Colonies have one common tariff under which catalogues, price lists, &c., are charged with a duty at the rate of 3*d*. per lb. The duty is waived on all packages sent through the post which do not exceed 4 lbs. in weight. On packages heavier than 4 lbs., duty should be remitted by postal or money order to the Deputy Postmaster-General of the State to which catalogues, &c., are addressed, and each package marked as above mentioned; if this is not done the duty will be collected as a surcharge.

The duty on catalogues sent through the post to Canada is 5*d*. per lb., and those requiring to prepay the duty can do so at any district post-office in Great Britain.

There is no tariff duty on catalogues sent by British firms (other than printers) to New Zealand, excepting on leaflets and circulars sent out in quantity for distribution.

Where a large number of catalogues are required to be distributed in any particular colony, the Manufacturers' Association recommend that catalogues should be forwarded in bulk to an agent on the spot, who should be requested to pay the duty and re-post them locally.

IN fulfilment of our announced intention of issuing a second Empire Number, that portion of the current issue occupied by special articles is devoted to the engineering features of the Transvaal, the State of Victoria, and the Crown Colonies. In addition a full description is given of that important structure recently completed in Natal, viz., the Connaught Bridge. Our purpose had been to include a brief consideration of Indian engineering developments in this

issue, but a persistent attack of low fever has unfortunately prevented our appointed contributor, Mr. John Wallace, of Bombay, from executing his commission in time for publication. Indian engineering in its various aspects is, however, scarcely to be handled in a single monograph, and we have under consideration the inclusion of Mr. Wallace's article in a later issue wholly devoted, so far as special articles are concerned, to India and the East.

As we are closing the pages of this number for press the sudden death from syncope is announced of Sir Benjamin Baker, K.C.B., K.C.M.G., F.R.S., at his residence, Bowden, Pangbourne. One of the greatest engineers of the period, his name is universally associated with original conceptions, bold designs, and ingenuity in execution, and to mention the Forth Bridge and the Aswân Dam, the two greatest undertakings of modern times, is to state his pre-eminence in the profession of which he was a member.

Sir Benjamin Baker was the son of Mr. Benjamin Baker, and was born at Carlow in 1840. He was thus in his sixty-seventh year. He received his earliest training in a South Wales ironworks, from which he passed, in 1861, to the engineering offices of the late Sir John Fowler, afterwards associated with him in more than one of the great undertakings which made them both famous. Work of a singularly varied character was done in Sir John Fowler's establishment, and there Benjamin Baker obtained a valuable experience in almost every branch of modern engineering. Very early in his career Baker had written a book on hanging span bridges, and had also read before one or other of the various engineering societies professional papers, which, by the originality of their treatment, gave promise of that eminence which he afterwards achieved.

In 1875 Baker became a member of Fowler's firm, and the record of their co-operation fills a large chapter in the history of British engineering. The building of the Forth Bridge, which structure was the greatest issue of their joint efforts, was the pre-eminent period of Sir Benjamin's career. Begun in 1883, the undertaking took nearly seven years to complete.

The bridge was opened by King Edward VII., then Prince of Wales, on March 4th, 1890. Including the approach viaduct, the extreme length of the bridge is a mile and half, while the actual cantilever portion of it is a mile and twenty yards. There are two spans of 1,700 ft. each, two of 675 ft. each, fifteen of 168 ft. each, and five of 25 ft. each. The structure rises 452 ft. above its foundation. The surface that had to be painted amounted to 135 acres, and the total weight of steel employed to 51,000 tons. Finally the entire work cost £3,177,000.

Sir Benjamin always recognised in the most ample manner the great share which Sir John Fowler had in its accomplishment. It is understood, however, that the idea of the cantilever construction originated with Baker. Not that the principle was new—cantilever bridges were built centuries ago—but the merit of the Forth Bridge lies in the successful application of the principle to new conditions.

Sir Benjamin Baker received the honour of K.C.M.G. on completion of the Forth Bridge in 1890, and on the opening of the Aswân Dam in 1892 was created K.C.B. He was elected a Fellow of the Royal Society; he was a member of the council of the Institution of Civil Engineers, and in 1895 became president of the institution. He was awarded the Poncélet prize of the French Academy of Sciences, and received many other distinctions at home and abroad. At the tercentenary of the Dublin University, he, with the late Lord Armstrong, was made Honorary Master of Engineering. He was also Hon. LL.D. of Edinburgh, and Hon. D.Sc. of Cambridge.

IRON, STEEL, AND THE FOUNDRY.

Conducted by PERCY LONGMUIR.

THE IRON AND STEEL INSTITUTE.

(Papers read at the May meeting.)

Carbon-Tungsten Steels. — Under this heading Mr. T. Swinden presents an exhaustive research dealing with the effect of varying contents of carbon in the presence of a constant percentage of tungsten. The steels investigated are crucible products containing approximately 3 per cent. tungsten, and giving a range in carbon of from 0·10 to 1·20 per cent. The mechanical properties of these steels in the normalised condition are fully recorded, but to some extent may be summarised in the following table of tensile tests.

Mark.	Analysis.		Elastic Limit.	Maximum Stress.	Elongation per cent. on 2 inches.	Reduction of Area.
	C per cent.	W per cent.	Tons per Square Inch.	Tons per Square Inch.		Per cent.
924 N	0·144	3·25	24·44	34·27	28·5	62·8
922 N	0·218	3·24	25·27	33·19	27·5	61·0
923 N	0·27	2·92	29·0	39·3	24·1	59·8
921 N	0·48	3·11	41·54	53·75	16·0	45·5
981 N	0·53	3·18	45·08	55·82	16·0	47·9
920 N	0·57	3·17	44·56	57·76	14·5	44·2
965 N	0·89	3·08	48·87	62·00	13·5	29·5
964 N	1·07	3·09	40·37	50·82	15·5	28·2
719 N	1·24	3·02	46·1	56·0	9·5	16·9

These tests clearly show the toughening effect of tungsten, especially as the carbon increases. Compared with iron-carbon steels the tenacity has been considerably increased, with only a slight lowering in the ductility, in fact at about 0·5 per cent. carbon the reduction of area is materially higher. A comparison of the elastic ratio of carbon and carbon-tungsten gives the following interesting figures (p. 443).

In studying the thermal transformations of these steels the author has devoted particular attention to the effect of initial temperature and of arrested cooling at certain definite points. This work clearly shows that the critical changes of ordinary carbon steels are not influenced by the presence of tungsten, provided the steel has not been heated beyond a certain maximum called the "lowering temperature." If initial temperature has exceeded this maximum the critical points are distinctly lowered and occur at a definite temperature functioned by the tungsten content. Tungsten thus appears to modify the molecular constitution at this particular "lowering temperature" in such a way as to result in an alteration of the change point from about 690° C. to 570° C. on cooling. The lowering temperature increases as the carbon rises from about 950° C. with 0·1 per cent. carbon to 1,120° C. with 1·2 per cent. carbon. The temperature to which the Ar. 1 point is lowered is practically constant at about 570° C. Rate of cooling does not affect the position of this point, since a steel

Carbon Steels.		Carbon-Tungsten Steels.		
Combined Carbon per cent.	Elastic Ratio per cent.	Combined Carbon per cent.	Tungsten per cent.	Elastic Ratio per cent.
0·08	57·0	0·144	3·25	71·3
0·21	67·3	0·218	3·24	76·1
0·38	61·4	0·27	2·92	73·8
0·59	46·3	0·48	3·11	77·3
0·89	47·3	0·53	3·18	80·8
1·20	57·9	0·57	3·17	77·1
1·47	57·9	0·80	3·08	78·8
—	—	1·07	3·09	79·4
—	—	1·24	3·02	82·3

heated to above 1,200° C. and then cooled to and maintained for two hours below the lowering temperature, still showed the change to occur at 570° C.

The Relation between the Process of Manufacture and some of the Physical Properties of Steel.—In this paper Mr. F. W. Harbord considers the question of how far steels of similar composition, but made by different processes, vary in physical properties. For this purpose a large number of tests have been made, and the results are given in conjunction with the composition and process of manufacture. These tables will prove invaluable for reference, but for the present this aspect may be summarised by reproducing one of the author's curves showing results obtained from steels of varying carbon content and process.

A consideration of the results shows that from 30-ton steel upwards about 0·10 per cent. more carbon is required in a basic open hearth steel than in an acid Bessemer steel to give the same result, and if engineers require material of the same strength made from the basic open hearth furnace as they have been accustomed to receive from the acid Bessemer, they must permit the manufacturer to increase his carbon approximately to this extent. The same applies in a much less degree to steel from the acid open hearth and the basic open hearth, but the essential point is that a reasonable increase in carbon must be permitted in order to obtain the same results. That this can safely be done is shown by practical experience, and also by the fact that the necessary elongation and reduction of area to satisfy all reasonable specifications can be obtained with this increase of carbon.

Finally the following table may be

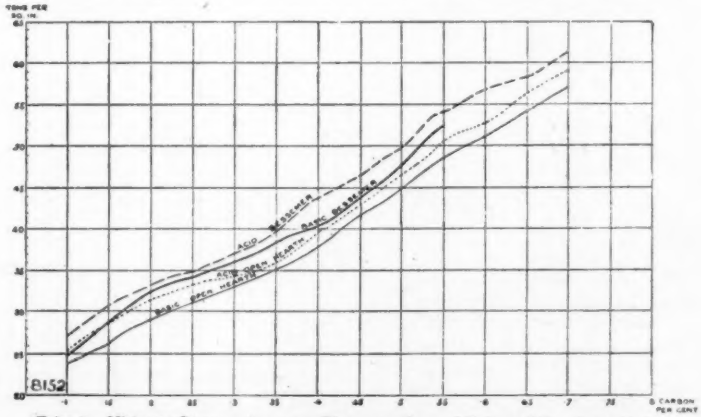


FIG. 1.—Ultimate Stress. Average of large numbers of Collected Results as Rolled.

THE RELATION BETWEEN THE PROCESS OF MANUFACTURE AND SOME OF THE PHYSICAL PROPERTIES OF STEEL.

regarded as a summary, and also as indicating the content of carbon required in different classes of steel to give the same tensile stress.

A method of producing High-class Steel from Pig iron containing Chromium, Nickel, and Cobalt.—Mr. A. Windsor Richards describes a process invented by Dr. Massenez for the utilisation of a peculiar quality of pig iron by which a steel is produced containing approximately 1·5 per cent. nickel, 0·25 per cent. cobalt, and 0·30 per cent. chromium, which possesses all the good properties of steel containing a much higher content of nickel alone, is much cheaper and very trustworthy. The iron referred to is produced from an ore of the following analysis:—

	Per cent.
Iron as received	45·69
Manganese	0·232
Chromium	2·35
Nickel }	0·90
Cobalt }	
Silica	12·32
Alumina	9·25
Lime	0·550
Magnesia	2·143
Sulphur	0·029
Phosphorous	0·02

The pig iron obtained from this ore contains 1·75 per cent. nickel and cobalt, 4 per cent. chromium, and 0·4 per cent. silicon. The problem of converting an iron of this type into steel, without serious trouble from the chromium, was a difficult one. Dr. Massenez, however, conceived the idea that if the iron were worked in a basic or neutral lined open hearth provided with slag notches, the chromium might be removed by forming successive voluminous quantities of oxidising slags, and as the chromic oxide was formed, removing these slags through the slag notches before they became too thick. This process was worked out at the Cleveland Works by the author, with the result that the greater part of the chromium was eliminated, but all the nickel and cobalt were retained in the steel. Details of the process are as follows:—Into an open hearth furnace is charged three tons each of lime and basic slag, and over this is added three tons of hematite ore. The mixture is heated until the ore becomes pasty and two ladles each containing ten to eleven tons of chrome nickel iron are then poured into the furnace. Thick and foaming slag is gradually formed, containing a portion of the chromium as chromic oxide, and this at the end of forty-five minutes to one hour is run out at the slag notches. A second slag is then formed from materials remaining on the bottom and by further

SHOWING PERCENTAGES OF CARBON REQUIRED TO GIVE SAME ULTIMATE STRESS IN STEEL MADE BY DIFFERENT PROCESSES.
EXPERIMENTAL BARS DEDUCED FROM CURVE.

	Steel of 25 Tons per Square Inch Ultimate Stress.				Steel of 30 Tons per Square Inch Ultimate Stress.				Steel of 35 Tons per Square Inch Ultimate Stress.				Steel of 40 Tons per Square Inch Ultimate Stress.				Steel of 45 Tons per Square Inch Ultimate Stress.				Steel of 50 Tons per Square Inch Ultimate Stress.			
	Basic Open-hearth.	Acid Open-hearth.	Basic Bessemer.	Acid Bessemer.	Basic Open-hearth.	Acid Open-hearth.	Basic Bessemer.	Acid Bessemer.	Basic Open-hearth.	Acid Open-hearth.	Basic Bessemer.	Acid Bessemer.	Basic Open-hearth.	Acid Open-hearth.	Basic Bessemer.	Acid Bessemer.	Basic Open-hearth.	Acid Open-hearth.	Basic Bessemer.	Acid Bessemer.	Basic Open-hearth.	Acid Open-hearth.	Basic Bessemer.	Acid Bessemer.
Carbon per cent....	0·128	0·110	0·075	...	0·28	0·18	0·17	0·13	0·37	0·340	0·26	0·243	0·440	0·404	0·380	0·350	0·510	0·473	0·451	0·430	0·590	0·567	0·545	0·485

AVERAGE RESULTS COLLECTED FROM VARIOUS SOURCES DEDUCED FROM CURVES.

Carbon per cent....	0·125	0·110	0·10	0·08	0·22	0·175	0·170	0·14	0·35	0·330	0·27	0·250	0·425	0·4 0	0·039	0·350	0·30	0·480	0·470	0·427	0·580	0·545	0·523	0·505

MEAN OF EXPERIMENTAL AND COLLECTED RESULTS.

Carbon per cent....	0·126	0.110	0·089	...	0·25	0·177	0·170	0·135	0·360	0·335	0·265	0·246	0·432	0·407	0·385	0·350	0·505	0·475	0·461	0·428	0·585	0·536	0·524	0·495

additions of basic slag, fluor spar and lime. This slag after melting contains further chromic oxide and is also removed, but owing to its viscous character it can only be made to pass the slag notch by mechanical assistance. This process of slag formation and removal is repeated according to the content of chromium in the iron, thus with an iron containing 4 per cent. chromium after the removal of the fourth slag the whole of the chromium is eliminated. From this stage the metal is worked down like an ordinary open hearth charge. The boil commences in from nine to ten hours after charging and only lasts an hour before the steel is ready for tapping. In making high carbon steel it has been found desirable to tap when the carbon has fallen to the required point, but failing this recarburisation is effected either in the furnace or the ladle by the usual additions. The resulting steels contain about 0·3 per cent. chromium derived from the reduction of chromic oxide in the slag. Should higher contents of chromium be required a sufficient quantity of chrome pig is added before tapping. Mechanical tests of the resulting steel have shown it to possess excellent properties, it is exceedingly tough and offers good resistance to mechanical shocks and stresses. Analyses of four steels and tensile tests obtained from them are embodied in the following tables:—

ANALYSES.

Cast No.	C.	Mn.	Si.	S.	P.	Ni.	Cr.	Co.
1	0·58	0·66	0·02	0·048	0·022	1·51	0·51	0·25
2	0·53	0·86	0·02	0·057	0·032	1·45	0·30	0·23
3	0·52	0·57	0·02	0·06	0·027	1·39	0·35	0·24
4	0·56	0·96	0·02	0·06	0·03	1·50	0·30	0·26

TENSILE TESTS.

Cast No.	Yield point. Tons per square inch.	Ultimate stress. Tons per square inch.	Elongation per cent. in 2 inches.	Contraction of area per cent.
1	32·10	57·90	13·00	26·50
2	33·60	54·50	13·00	22·50
3	29·50	57·20	12·00	20·50
4	33·80	60·00	12·50	20·70
*4	33·40	58·40	19·00	32·70

* Reheated to 650° C.

The Manufacture of Steel from high Silicon Phosphoric Pig iron by the Basic Bessemer Process.—In this paper by Mr. A. Windsor Richards, the successful utilisation of siliceous pig iron in the basic process is indicated and the fact that ordinary grey Cleveland pig iron of low sulphur content has been satisfactorily blown in a basic converter. Briefly, the process has been suggested from studies by Dr. Massenez, who reached the conclusion that if the siliceous slag which is first formed in the converter could be rendered sufficiently fluid for removal, then ordinary Cleveland iron could be used for making good steel, thereby obviating the use of foreign ores for the manufacture of special basic iron. Trials by Mr. Windsor Richards proved these conclusions to be correct, and the process was therefore adopted by Messrs. Bolckow, Vaughan & Co. in July, 1905. It has been continuously used since, giving good results, yielding a fine and uniform quality of steel.

In working the process, iron oxide, with or without small quantities of lime, is charged into the basic converter and the molten charge of grey Cleveland iron added. The silicon of this iron will vary from 1·5 to 3·0 per cent., but the sulphur is always low. The charge is blown until the silicon is oxidised, and on the appearance of the carbon flame as much as possible of the perfectly fluid siliceous slag poured off. This slag does not affect the linings to any appreciable extent owing to the low temperature during the first blowing, for while there is a little corrosion on the sides of the converter, the bottoms give a better life, the net result being that the same quantity of dolomite per ton of steel is used now as when using special basic iron. The final slag contains 8 to 11 per cent. iron, 14 to 20 per cent. phosphoric acid, and 11 to 12 per cent. silica. Practically the whole of the iron in the oxide, added for desiliconising, is reduced and passes into the metal, thus improving the yield. The yield is 87½ per cent. as against 84 per cent. by the old process. The advantages of the process are summarised as:—(1) An improved quality of steel, the phosphorus being under better control. (2) A high carbon steel for rails can be produced with the greatest regularity. (3) The utilisation of native ironstone without foreign additions. (4) Reduced loss on blowing in consequence of less iron being ejected from the converter, less oxidation and direct reduction of a portion of the oxide of iron additions. (5) Cleanliness of working, involving less labour. (6) Rich fertilising slag from pig iron containing 1·5 per cent. or less of phosphorus.

Note on the Distribution of Sulphur in Metal Ingot Moulds.—In this note, Mr. J. Henderson directs attention to the distribution of sulphur in ingot moulds made from hematite pig iron.

	No. 1.		No. 2.		No. 3.		No. 4.	
	Top. Per cent.	Bottom. Per cent.	Top. Per cent.	Bottom. Per cent.	Top. Per cent.	Bottom. Per cent.	Top. Per cent.	Bottom. Per cent.
Sulphur	0·206	0·034	0·083	0·032	0·075	0·031	0·226	0·058

The fact that sulphur is higher in the tops of ingot-moulds and other large castings is, or should be familiar, and this being the case it is obviously unfair to sample only the top when estimating sulphur. As an example the following results are given.

Nos. 1, 2 and 3 were made from pig iron containing a maximum of 0·030 per cent. of sulphur. To ascertain how far down into the mould excessive sulphur extended, a piece from the top of a large mould was drilled from the top to a depth of eight inches and each inch tested for sulphur, with the exception of the first inch, which was divided and each half inch tested separately. The results are as shown in foregoing Table.

	Sulphur.	Combined carbon.	Manganese.	Silicon.	Phosphorous.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1st inch { 1st half inch	0·198	0·29	1·12	1·26	0·043
1st inch { 2nd ,,	0·142	0·41	1·06	1·21	0·043
2nd inch	0·082	0·44	1·03	1·26	0·044
3rd ,, ...	0·055	0·46	0·99	1·26	0·042
4th ,, ...	0·047	0·46	0·95	1·26	0·042
5th ,, ...	0·043	0·46			
6th ,, ...	0·041	0·46	0·95	1·26	0·042
7th ,, ...	0·041	0·46			
8th ,, ...	0·042	0·46			

These results show that excessive sulphur does not go deeper than the first inch, and that after the second inch there is no reason to find fault with the composition of the mould. It will be noted that the lowest percentage of combined carbon is associated with the highest sulphur, a feature contrary to that usually found with pig iron. The explanation of the anomaly in this case is no doubt found in the sulphur existing as a segregate of sulphide of manganese and thus its usual effect of hardening the iron by assisting in the retention of carbon in the combined state is not exerted.

NEW MACHINERY AND APPLIANCES.

The Editor cordially invites early particulars of New Machinery, Improvements, Novelties, &c., for inclusion under this section.

Chain Testing Machine.

Testing machinery of every description is at the present time receiving so much attention that we are glad of an opportunity of illustrating one of two 30-ton chain-testing machines that have been recently completed for a northern railway company, by Messrs. W. & T. Avery, Ltd.

The machine consists of a cast-iron hydraulic cylinder and piston forming the straining portion, and a cast-iron lever and steelyard forming the weighing or recording portion. These are placed at opposite ends of two rolled steel joists which form a compressive column to take the strain applied to the chain specimen. The hydraulic cylinder is provided with a piston and piston rod, and is designed to work with an hydraulic pressure of 750 lb. per sq. in., and both cylinder and piston are provided with the usual hydraulic leathers. At the top of the cylinder is a double valve of the plunger type to control the direction of the pressure supply either to the front or to the back of the piston as desired. The weighing or recording apparatus consists of a cast-iron main lever fitted with hardened steel knife-edges, the length of these knife-edges and the distance between them being

HYDRAULIC CHAIN TESTING MACHINE. CAPACITY 30 TONS.

in accordance with the regulations issued by the Board of Trade. The fulcrum knife-edge bears in hardened steel bearing blocks fitted into recesses in pedestals cast upon the main cross head, while the main knife-edge is connected to the main shackle, having a hardened steel bearing block. The steelyard is of cast-iron fitted with hardened steel knife-edges, and has a graduated scale plate divided into tons and sub-divided into 1-100th tons by a vernier scale upon the sliding poise. The graduations range from zero up to the full capacity of 30 tons. The poise is mounted upon four rollers which run upon tracks upon the steelyard, and the poise itself is actuated by a central screw which is rotated by means of bevel and spur wheel gearing.

The gearing is controlled by a hand wheel at the front of the steelyard. In this arrangement the pressure of the hand upon the hand wheel has no effect upon the steelyard, and consequently inaccurate readings are impossible. This advantage is secured by arranging the gear so that the hand wheel, which is carried in a bracket bolted to the steelyard column and has attached to it a spur wheel, communicating its motion to a second spur wheel carried by a bracket bolted to the steelyard itself, the meeting point of the gearing being at the fulcrum knife-edge. The rise and fall of the steelyard is controlled by means of a cast-iron column having a wrought iron shank fitted with suitable buffer springs.

The chain specimen is held in two cast steel slippers, one of which is attached to the main shackle and the other is secured to the piston rod.

Any size of chain from 3-16 in. diameter up to $1\frac{3}{4}$ in. can be tested in this machine, chains from $\frac{3}{4}$ in. up to the maximum size being inserted direct into the slippers, while sizes of chain less than $\frac{3}{4}$ in. diameter are secured in loose holders, which are themselves secured in the slippers.

Bower's Plate Micrometer Gauge.

A new form of plate micrometer gauge, details of which are shown in the accompanying illustration, has been recently introduced for the purpose of taking accurate measurements with the dividers or compass points, where fine and accurate measurements and layouts are required.

The principle of the apparatus is as follows:—

The plate *A* is called the base plate,

PLATE MICROMETER GAUGE.

which has a spiral hair line cut on its face that starts from the dead centre and expands exactly $\frac{1}{20}$ (or ·05) in. in each complete revolution.

The face of *A* is then divided into five equal parts by radial lines marked 0 to 4 which divide the spiral lines between each radial line into $\frac{1}{100}$ or (·01) per in. The sector *B* at its outer or circular edge is exactly equal to one of the radial divisions of *A* and is divided into ten equal parts which divide the spiral lines on *A* into $\frac{1}{1000}$ or (·001) in.

The radial edge of the sector B is divided into tenths and twentieths or (·100 and ·050) in., and when the radial edge of *B* is placed on radial line *O* on *A* both radial and spiral lines will exactly cut each other, which is the zero position of the gauge.

If we want a measurement of say 1·235 we revolve the sector *B* till the fifth line on its circular edge is on the third radial line on *A*. We then look at 1·2 in. from the centre *C* on the graduated radial edge of *B*, and the dimensions will be found by taking the first spiral line above the 1·2 in., which is made up as follows, viz.: The 1·2 in. on radial edge of *B* + $\frac{3}{100}$ or (·030) and + the $\frac{5}{1000}$ or (·005) on circular edge of *B*, or (1·2 in. + ·030 + ·005 = 1·235 in.). All measurements should be taken from the centres on *B* and off the hair line indicated on *A* and close up to the graduated edge of *B*. The capacity of the gauge is 4 in. and when more than 2 in. are required centre *D* is used, and for more than 3 in. use centre *E*.

Expressed simply, the first decimal point is found on the radial edge of the sector,

the second on the plate, and the third on the circumference of the sector.

The apparatus should be found a valuable addition in every shop and drawing office, and in colleges and higher grade schools where fine measurements are taught, as it not only should teach the students to work to a fine limit of accuracy, but should give them a good understanding of the decimal sub-divisions of an inch.

The plate micrometer, which is made by Messrs. B. J. Hall & Co., 39, Victoria Street, S.W., measures all sizes in inches from zero to 4 in. by one-thousandth of an inch, and in metric from zero to 10 c.m. by one-hundredth of a millimetre.

"I Section" Motor Car Axles.

The recent accidents caused by either breakage of motor car axles, or the axle being broken by the upset, appear to be responsible for a difference of opinion amongst motor car manufacturers as to the various types of front axles.

The "Napier" cars are being fitted with those of "I" or beam section, which, regarding the axle simply as a beam supported at its ends and loaded at the spring seatings, is a section generally accepted, it being quite unusual to use a tube as a beam in general engineering.

With a tubular axle it it necessary to braze the tube into a stamping forming the end; this stamping is subjected to a severe stress, which tends to bend it up at the spring seat and wrench the tube from its socket.

Further, the tube is originally straight, and requires in most cases to be bent or set to give clearance. The tube must be bent very carefully to ensure that it does not develop cracks, and it must also be carefully annealed to ensure that it has not become brittle.

In the accompanying illustrations the top view shows the "Napier" axle only. The second view shows it with the steering swivels attached, and the third shows it with all the component parts clearly set out, including the ball races and bolts that support the weight of the car on the steering swivel, and ball bearings that fit on to the end of the axle to carry the front wheel,

"I SECTION" MOTOR CAR AXLE.

and the last view shows the axle set up with its front wheels attached to its steering bar so connected, as is usual in Napier practice, that the cross bar when running is under tension and not under compression, the latter of which is mechanically bad.

5-Inch Self-Acting Lathe for Motor Work.

Messrs. Drummond Bros., Ltd., Guildford, have recently introduced a useful lathe which has been specially designed for the purpose of repairs to motors and motor cars, and is stated to be the only lathe of its size constructed with a special view to this class of work. It is claimed that with it any ordinary mechanic need send no repair whatever out; such delicate and precise work, for instance, as the re-boring of a pair of twin cylinders can, owing to its peculiar construction, be done on it, an operation which on an ordinary pattern lathe could only be done by a skilled operator.

The tool has a high general capacity and power, and is stated to be capable of dealing with work for which a 6-inch lathe of common pattern would be required. For instance, it will take a good deep cut in rough, hard cast-iron with the scale on, on pieces 14 ins. in diameter, by treadle, although its capacity for light and extremely accurate work is equal to a small precision lathe.

The following are a few of the improvements introduced in the design:—

The slide rails on which the saddle is guided, are formed at the level of the bottom of the

gap, and extend along the gap space, instead of being formed at the top level and stopping short at the gap space. The saddle can, therefore, be worked at any time over the gap space and right up to the largest face plate running in the gap, without any overhang either of tool or saddle. The advantage of this for facing work of large and thin dimensions will be obvious.

There being no necessity for a gap piece, all the trouble of removal, cleaning, and replacing of this is avoided, and an even wearing surface, equal to a straight-bed lathe, is secured, although the convenience of the gap is retained.

This design of bed gives a true box form of casting with heavy side gibs, as well as the usual cross braces. Such a form is, of course, stiffer and more rigid than the common form which is slit right through from end to end to form the ways for the tail-stock guide.

The cross slide of the compound rest is formed by a slotted, truly surfaced, boring or milling table of large dimensions. On this, not only ordinary boring can be conveniently done, but holes parallel with each other in the same casting, such as twin motor cylinders, &c., can be bored at one setting; the distance, centre to centre, being readily obtained by the micrometer attached to the cross slide screw.

This table has self-acting cross-feed as well as longitudinal, making the lathe equal to a first-class "Lincoln" type milling machine for all purposes not requiring a vertical slide. The undoing of one nut only brings the upper slide away, leaving this table clear for fastening work to.

Other details of the specification include: double-geared head-stock, cut gear; hollow mandrel accurately ground, running in concentrically adjustable parallel bearings; extra large 3-speed cone for flat strap, set over poppet head, with long bearing steel barrel; square thread actuating screw; extra long sliding saddle with long wings; recessed cross slide, carrying slotted boring and milling table and compound slide rest with top slide to swivel completely round and graduated for taper turning; self-acting motion to surfacing slide and boring and milling table, extra large steel square thread draw screws, micrometer adjustment to cross slide; accurately cut steel square thread lead screw full length of bed; fitted close up to and under saddle guides and protected by them from cuttings; steel square-thread feed screw full length of bed; quick return action to saddle by hand-wheel rack and pinion.

The machine is fitted with a greatly improved motion, with a practically frictionless drive on large discs, and new form of light treadle, with diagonal draw-rod to bell-crank lever.

THE ENGINEERING PRESS.

In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.

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TRADE LITERATURE.

Loveridge, Ltd., Docks, Cardiff. Circular of the Couve's automatic wave subduer for distributing oil on the sea in stormy weather.

A. Vernet, 11, Queen Victoria Street, E.C. Catalogue of punching and shearing machines.

John Rusco & Co., Ltd., Hyde, Manchester. Circular of the "Triumph" cable drum carriage (Turner's patent).

Alfred Herbert, Ltd., Coventry. Sectional catalogue E of modern capstan lathes.

Crompton & Co., Ltd., Salisbury House, London Wall, E.C. Sectional list U 12 of electrical pyrometers.

Diesel Engine Co., Ltd., 179, Queen Victoria Street, E.C. Illustrated catalogue of the "Diesel" oil Engine.

Bullivant & Co., Ltd., 72, Mark Lane, E.C. Booklet describing recent ropeway installations at Clacton-on-Sea, Simon's Bay, Preston and over the River Richmond, N.S.W.

Heenan & Froude, Ltd., Worcester. Catalogue No. 15 of mining machinery, in Spanish.

Darlington as an Industrial and Residential Centre. A booklet published by the Commerce Committee of the Darlington Town Council, dealing with the advantages and possibilities of the town.

Pearson, Sons & Co., Ltd., Nitshill, Glasgow. Pamphlet describing an apparatus for the complete combustion of coal in boiler and other furnaces.

Climax Patents, Ltd., 42, Spring Gardens, Manchester. Catalogue of "Stox" pneumatic hammers.

Alfred Herbert, Ltd., Coventry. Sectional list A, part 6 of milling cutters and tools.

Cape Asbestos Co., Ltd. Pamphlet descriptive of the firm's blue asbestos removable coverings.

Siemens-Schuckert Werke, Berlin. Well-illustrated album of electric locomotives produced by this firm.

Gripper Co., Ltd., 2, Bream's Buildings, W.C. Leaflet relating to the "Gripper" nut and bolt lock washer.

American Locomotive Co., New York. Pamphlets dealing with 10-wheel type locomotives weighing more than 150,000 lbs., and light locomotives.

Valor Co., Ltd., Aston Cross, Birmingham. Several booklets relating to the firm's new "Erle" fire extinguisher.

Gent & Co., Leicester. New general telephone catalogue. Amongst other things are listed the "Parsons-Sloper Secret" telephones, which have been adopted by the G. P. O. for all intercommunication in the Government offices throughout the country, as well as "Regent" telephones, which have also been adopted by the G.P.O.

J. Samuel White & Co., East Cowes. Descriptive pamphlet of the "White-Forster" patent water tube boiler.

The Phoenix Dynamo and Motor Co., Ltd. A useful embossed copper ash or pen-tray, a number of which they are distributing amongst their clients.

Samuel Denison & Son, Ltd., Leeds. Pamphlet dealing with the "Blake-Denison" continuous weigher for use with conveyors.

Kramos, Ltd., 47, Victoria Street, S.W. Complete list of portable electric tool equipments and electric hoisting machinery.

Mather & Platt, Ltd. 4th edition of Multipolar Dynamo List.

MANUFACTURERS' NOTES.

Thermit, Ltd. *v.* **Weldite, Ltd.,**—Judgment has been given in the High Court of Justice, Chancery Division, by Mr. Justice Warrington in the above action, which was brought to restrain the infringement by the defendants, Weldite, Ltd., of Parr's Bank Buildings, York Street, Manchester, of the Patent Alumino Thermic Process for the production of pure metals, and for welding iron and steel. The defendants claimed to have worked under a separate patent of their own, and contended that the plaintiffs' patents were invalid by reason of want of subject matter and prior user. Mr. Justice Warrington held that the patents on which plaintiffs proceeded were perfectly valid, that defendants' process of welding was only a colourable variation of plaintiffs', and granted an injunction restraining further infringement with costs.

Mountain & Gibson, Ltd., Electrical Tramway and Railway Engineers, Bury, Lancashire, have removed their London Offices to more commodious premises in Albert Buildings, 49, Queen Victoria Street. London, E.C. The care of the London sales department will be in the hands of Mr. F. W. Newman, director, as heretofore, but he will now be joined by Mr. N. McL. Lawrence, director, who will attend more particularly to the engineering and technical work.

The Dexine Patent Packing & Rubber Co, Ltd., Stratford, have found it necessary to issue the following warning: "It having come to our notice that spurious imitations of our "DEXINE" conical gauge glass rings are being placed on the market, proceedings will be immediately taken against any person infringing our trade mark "DEXINE." None are genuine without the word "DEXINE" marked on the flange. When indenting for our rings specify trade mark "DEXINE."

SECOND PRIZE COMPETITION FOR ENGINEERS.

With the object of encouraging readers of The Engineering Review to communicate their ideas and experience on subjects of engineering interest, a prize of £10 was offered for what was, in the opinion of the Editor, the best article on one of the under-mentioned subjects:—1. The Relative Value of Planing and Milling. 2. Electrical *v.* Mechanical Driving. 3. Bonus Systems of Payment for Labour.

The award has been made to Mr. Walter Duckitt, 54, Church Road, Northfield, Birmingham, for his article on Planing *v.* Milling. Meantime we have decided to give another

PRIZE OF £10

for best article on one of the following subjects under the conditions given below:—

1. Live Steam Feed Heating.
2. Flame Arc Lamps.
3. The Management of Steam Turbines.

Instructions and Conditions.

Articles must not contain less than 2,000 words, and must be written on one side of the paper only, and be signed by the competitor.

Drawings and sketches must be on separate sheets of paper.

A short biographical sketch of the competitor's technical experience should accompany the article.

The right is reserved of publishing the prize article, and also any of the others sent in; but in the case of the latter, payment will be made for the same at our usual scale rates.

The Editor's decision in all matters connected with the competition shall be final, and binding on all the competitors.

All articles should be addressed to the Editor of The Engineering Review, 104, High Holborn, London, W.C., and marked on the outside, "Competition," and the same must be received not later than August 1st.